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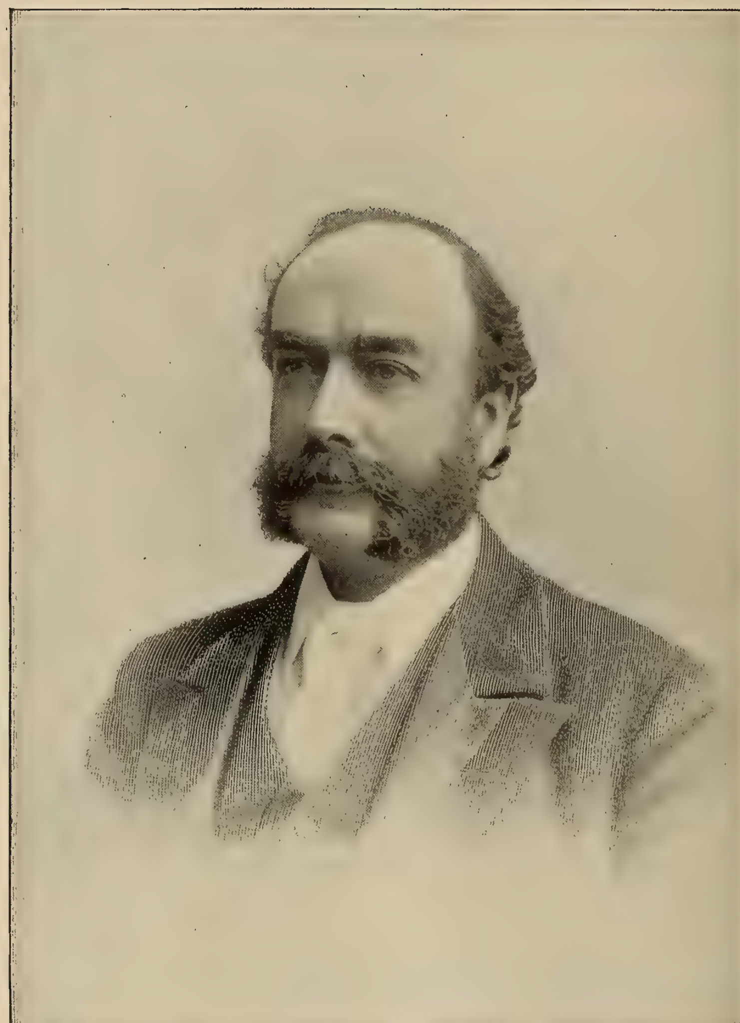

PHOTOGRAPH BY WAYLAND, BLACKHEATH.

A. F. Yarrow

(See page 83.)

CASSIER'S MAGAZINE.

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GEOLOGICAL KNOWLEDGE IN MINING.

By T. A. Rickard, State Geologist of Colorado, U. S. A.

IN November, 1851, when the rush to the newly found Australian gold diggings at Ballarat was daily increasing, Governor Philip, accompanied by his staff, rode to the scene of the gold discoveries. Having reached the camp he and his aides visited the workings at Golden Point and watched the "boys" at work, winning the gold from gravel that lay in the bed of the stream.

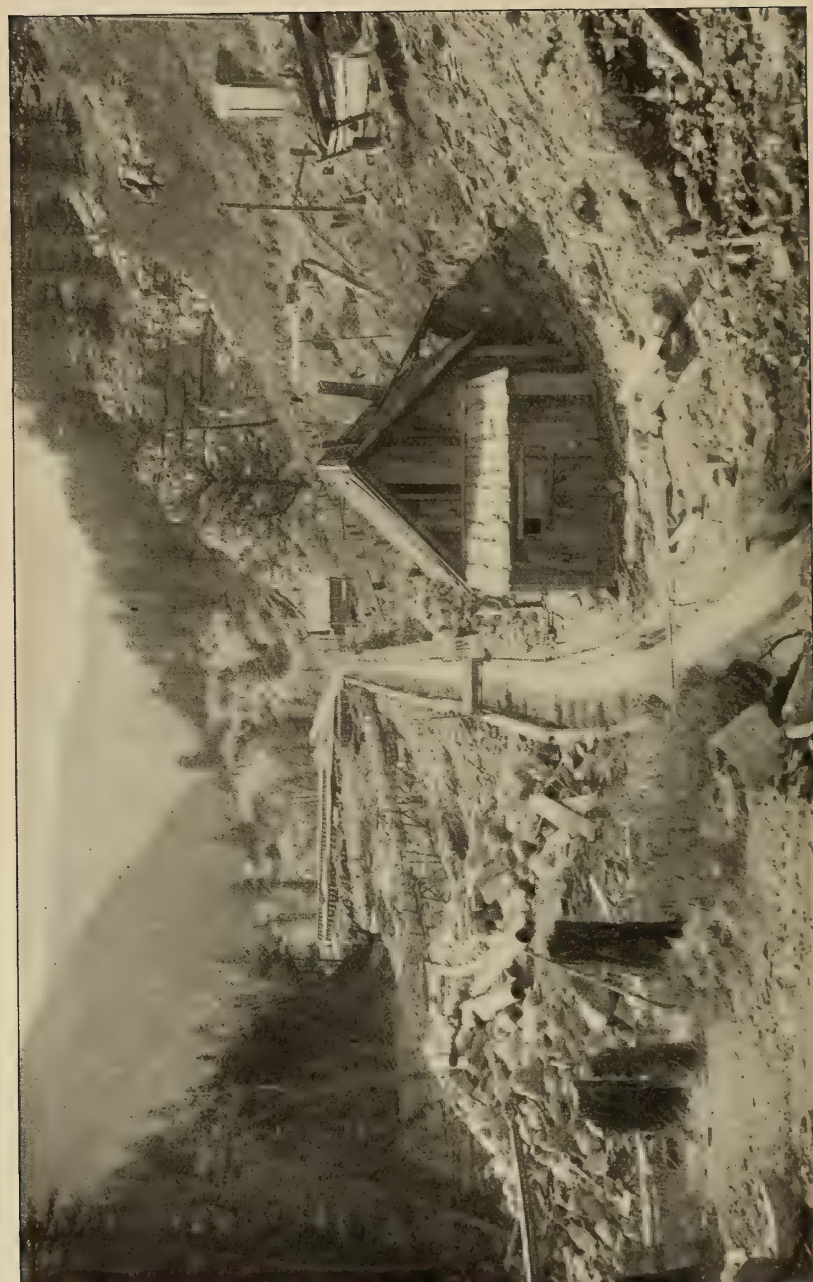
The Governor chatted with many of them and finally found himself conversing with an old Cornishman of more than average intelligence. The quaint dialect of the old fellow and his strong common sense pleased him immensely. Before leaving, he bethought him to put a question which many have asked since,—"And where do you think the gold came from?"

The old chap scratched his head, and, leaning on his shovel, looked up into His Excellency's face and replied, "Wheer it is, theer it is; and wheer it ain't, theer be I."

Could the statement of geological vision and the epitome of mining realisation be placed in plainer contrast?

Since that early day in the golden era of Australian development Ballarat has grown into a large and permanent mining region, the whole industry has

PANNING GOLD.



SLUICE BOXES OF A PLACER MINE.

gained an importance in the affairs of men which neither the genial Governor nor the philanthropic old miner could possibly have anticipated. Despite the vagaries of speculative epidemics and the queer vicissitudes of discovery the search for gold has become less of the haphazard suggested by the homely cynicism of the above story.

The newspaper scribbler, in want of fresh copy, has a habit of telling tales of blind luck and happy accident. A drunken fool falls down on the hillside and wakes from his turbid dreams to find himself resting against a ledge of white quartz gleaming with the yellow metal; or an idle shepherd picks up a stone to throw at a stray sheep, and, realising its unusual weight, shatters it against a boulder to find it the open sesame to the caverns of Aladdin.

Don't believe it! The blind goddess Fortune directs the miner's destiny less frequently than the brotherhood of pluck, energy and observation. There is as much luck in mining as in all things human, but hardly more; there is as much room for intelligent design and careful foresight as in any other business, and probably more.

Illustrations borrowed from fact will be of service. When Thomas Kruse, at Marysville, Mont., in the United States, was opening up the mine which made him a millionaire, there came a story of an old man driving a tunnel into a mountain at a place where he would find macadam for the road but no ore for the mill. When the crosscut intercepted a wide vein of rich stuff, men pointed to the incident as another evidence of the hit-or-miss character of ordinary mining. The real facts were far otherwise.

"Old Tommy Kruse," as he is known all over Montana, was a very shrewd and sensible prospector. He had found the outcrop of a promising lode on the mountain-side and had realised that, while one man alone cannot sink a shaft a hundred feet deep, he can, with his own unaided energy, drive a tunnel for several hundred feet. The tunnel cut the vein, whose position he had previously determined. So was begun the exploitation of a mine which has become famous in mining annals as the Drumlummon. It now has about twelve miles of workings out of which has come ore of a value approximating $14,000,000 (£2,800,000).

The Enterprise mine at Rico, in Colorado, was discovered by David Swickhimer. Picturesque stories are told o

A MINE OPENING.

the timely aid of a lottery winning and of the haphazard penetration into a big ore body. The truth is quite as romantic. Never were correct reasoning and indomitable pluck more fittingly rewarded.

Swickhimer had been working for wages in the ground of the Swansea Mining Company, on Newman hill. He had learnt the course of the veins which were being there successfully worked, and this knowledge was particularly valuable because the true rock,—sandstone and limestone,—is, in this locality, overlain by several hundred feet of boulders and gravel of lacustrine origin.

A MINE TUNNEL.

The veins do not reach the surface of to-day, and hence have no cropping to indicate their position.

Swickhimer left the Swansea mine and located a claim, the Enterprise, to the north. He began the sinking of a shaft only to find that the porousness of boulders caused a flow of water which hindered progress and made the work very expensive. A pump was at length purchased and it replaced the bucket and windlass.

But in the meantime the Swansea Company was pushing its levels ahead and would soon penetrate into Swickhimer's claim. Unless he found ore in place his location would, by the terms of the absurd American mining law, be invalid. The sinking of the shaft was hurried with a tireless energy which surmounted all sorts of bad luck. Eventually ore was struck and the plucky adventurer won his fortune. Since then the Enterprise mine has produced $3,500,000 (£700,000) out of its eight miles of underground workings.

And yet another instance! Among the Colorado mines the Little Johnny, at Leadville, has won a distinguished name. The uncovering of its riches was also the recompense of intelligent perseverance. The relative position of the beds enclosing the ore measures of Leadville has been accurately determined by geological survey, and despite faults which break the continuity of the stratification, it is possible, in the well developed parts of the mining area, to premise, with striking exactitude, the depth at which the various layers of rock will be intercepted by the sinking of a shaft.

As the flat lode of ore, enclosed by the sheets of porphyry and beds of lime, extends eastward, it changes in character, and, in places, becomes more important for its gold than its silver contents. George Campion and his associates began the sinking of a shaft on the plateau of Breece hill, but owing to the heavy influx of water and the soft character of the ground the undertaking consumed so much money that they abandoned it.

About the time when silver mining was temporarily disorganised by the closing of the Indian mints, his brother, John Campion, persuaded certain of his

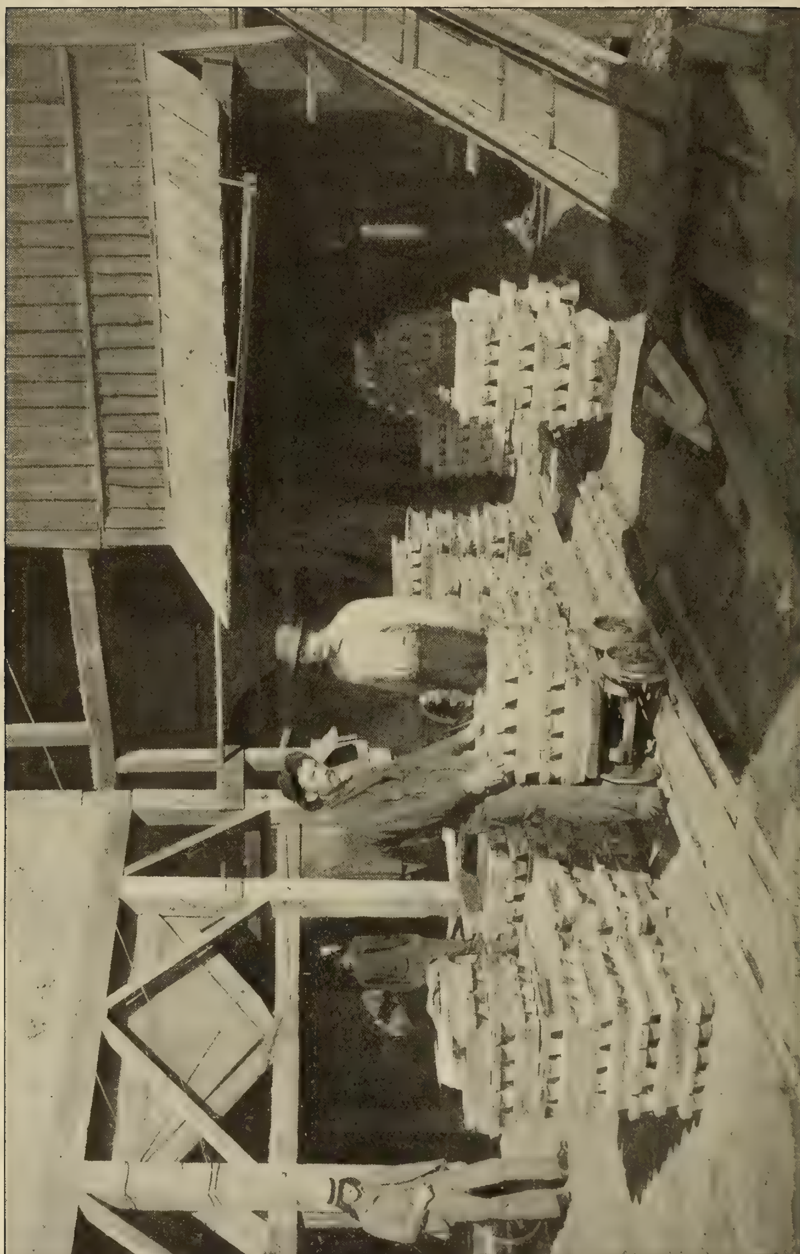
friends to join him in another effort to penetrate the porphyry overlying the ore horizon. The sinking of the shaft was resumed and successfully concluded in the heart of an immense ore body, which subsequently made the mine one of the most important gold producers in the State. Last year the output approximated $7,250,000 (£1,450,000).

Other stories of discovery would convey the same lesson. The last two related are particularly instructive, because they prove the direct commercial importance of a correct knowledge of geological structure. It is only within a comparatively recent period that the young science of geology has served as a handmaiden, guiding the faltering footsteps of the old industry of mining. The search for the hidden ore was a blind groping in the dark until the elucidation of the architecture of the underground world gave a light wherewith to illumine the miner's exploration.

IN THE LOWER LEVELS.

Newman hill, in Colorado, bears strong testimony to the money value of scientific methods. When first opened up, the veins were followed until they were found to break off abruptly. Operations ceased. It was a blundering sort of perseverance which first led to the discovery of the continuation of the veins, but it was trained observation which explained that the breaks or faults

HYDRAULIC MINING



BULLION AT A SMELTER.

follow known laws and that these laws find expression in rules by whose guidance much groping underground is made unnecessary.

Later on, when the veins were discovered to cease in their upward course at a certain horizon several hundred feet below the surface, not only of today, but of that former geological epoch which saw the deposition of the boulder drift, and when that horizon was proved also to be richly orebearing, there came the idea of a flat ore-bed capping the fissure veins and giving them a portion of its richness by the agency of downward flowing mineral solutions. How misleading this theory was we now know, and those also know who paid for the tangled web of fruitless levels and crosscuts to which that misconception gave rise.

On the other hand, the recognition of the fact that no ore-bed existed, but that the mineral of the so-called "contact" horizon occurred in bands which exactly followed the strike of the veins, which had originated them, clarified the situation and rendered well-directed prospecting easy.

Leadville, too, is a striking and more famous example of the application of geological knowledge to mine exploration. The constructive imagination of the scientist here comes into play. By an accurate determination of facts, following upon carefully recorded observations, he pictures the lay of the land as it was when those sediments were laid down in the sea, which now, by the transmuting force of nature's alchemy, have become converted into stubborn rock. Then, from the evident traces of the disturbances which they have undergone, he deduces the changes produced in their position, and thus, from the disordered fragments, he reconstructs the orderly structure of a bygone age.

The Leadville beds have been broken by faults which are measured in dislocations of hundreds of feet. Where a bed now appears at the surface at one place, its former continuation is to be sought for by a shaft a thousand feet deep. In the same way, the ore, which here is in the form of a flat bed, conformable to the stratification, is found at a varying distance from the surface, determined by the play of the forces which also formed the mountain ranges now serenely overlooking the valley of the Arkansas. Whether you are east or west of a fault decides whether a few feet and a hundred dollars, or a deep shaft and a fortune, are required to be sunk before you reach the ore.

A DEEP-LEVEL TUNNEL.

In Australia the district of Bendigo is known to mining engineers because of its anomalous ore deposits. When the shallow gold-bearing alluvium was exhausted, and work was begun on the quartz veins whose outcrops appeared in the bed rock under that alluvium, it was found that the golden ore did not

persist to any great depth. The camp seemed destined to a speedy ending, when other shafts found that, though the quartz veins died out, others, roughly parallel to them, were to be discovered underneath, which, in turn, gave place to similar ones. And, so, in process of time, a big mining industry was developed.

But this was accomplished at a great waste of time and money until the geologist gave the miner the key to a puzzling maze of intricate phenomena, by pointing out that the veins were true anticlines or saddles—that is, that the quartz followed the folds in the slates and sandstones.

Take a pamphlet and bend it! The sheets of paper will form a space at the apex of the arch which you make. Let these represent beds of rock and let the spaces be filled with quartz. If now the plane of the surface cuts through these there will appear two veins of quartz bending toward each other, these two having been, previous to erosion, parts of one continuous overarching bed of quartz.

In a depth of two thousand feet there would be found, at Bendigo, from ten to twenty-five of these saddles, and out of such a number half a dozen would probably prove profitable. This district has now thirty shafts over 2000 feet deep, and several over 3000 feet, of which one (Mr. Lansell's "180" mine) sinks to 3350 feet from the surface, and is the deepest gold mine in the world.

The fact that the ore followed the bedding planes of the enclosing rocks was not recognised because the pressure to which they had been subjected had induced new planes of cleavage, obliterating the former lines of sedimentation. But very conclusive proof of the original position of the beds was obtained when ripple marks were found covering the sandstone forming the "wall," or bounding plane, of a quartz vein.

The corrugations upon the surface of rock, seen far underground, were the hieroglyphics whose decipherment told the whole of the ancient story. The crests of the waves, in the sandstone, were about three inches apart, and presented all the little irregularities to be seen to-day when the wind blows over the shallow waters of an estuary and imprints the evidence of its action upon the yielding sand.

The markings had been protected by layers of mud. The mud had become slate, and the sand, sandstone. Between them, as within the pages of a book, had been preserved the conclusive proof of the original position of the beds, enclosing a vein which had been formed in later geological days when fissuring had made a passageway for the circulation of underground waters and the deposition of the goldbearing quartz.

Thus, we permit our minds to travel back to those remote ages when silence brooded over the dim vastness of the Silurian seas, when neither bird sang, nor flower grew, when the winds wandered over leafless lands, and, stirring the shallow waters of a quiet inlet, left those indentations in the yielding sand which, as ripple marks, we now find, hundreds of feet underground, imprinted in unyielding rock. Then the imagination sweeps through the long remoteness of the times of waiting which intervened until man came,—man, who in his restless energy and unsatisfied desires, broke through the beautiful covering of the sunlit earth, to grope below for things prepared for him since the beginning of the world.

DISCHARGING AND STORING GRAIN AT BRITISH PORTS.

By William G. Wales.

A partial reprint of a paper read before the British Society of Engineers, with a number of new illustrations specially added for publication in this magazine.

NO other nation in the world depends so entirely on other countries for sustenance, and lives under such extraordinary conditions as regards its food supply, as does the English. Every year Great Britain sees a greater importation of wheat and cereals, and at the same time a less amount of home-grown wheat, and yet little is said and nothing is done to check or lessen the gravity of the situation.

Twenty-five years ago the import of wheat, and flour reckoned as wheat, was (taking the average of the last five years at that period), 8,727,541 qr. per annum, whilst the import of wheat in 1895 was an average of 22,044,413 qr. This increase is by no means altogether due to the increase in population, for the Registrar-General's returns for the years 1870 and 1895 show an increase in population by 25 per cent., against an increase by the above figures of 152 per cent. in imported wheat. By referring to wheat statistics, it is found that the available amount of bread-stuffs for consumption per head per annum has increased slightly, but not enough to account for the largely increased imports, and therefore this disproportional increase must be due to the decay of agriculture in Great Britain. Twenty-five years ago the home produce of wheat was (taking the average of the last five years at that period) 13,245,194 qr., whilst the average of the last

WATERLOO DOCK AND GRAIN WAREHOUSES AT LIVERPOOL.

ANOTHER VIEW OF WATERLOO DOCK.

five years to-day is only 7,201,250 qr., or a diminution of 45 per cent.

The same state of affairs exists with regard to other kinds of grain, although perhaps not quite in the same degree. The decline in home-grown wheat may be said to have been going on for the last twenty-five years, and still shows no sign of abatement. It is a matter of national importance, and one which should not be underestimated. The more dependent Great Britain is on foreign countries for her food supply, the more efficient must be her navy to protect that supply from being cut off in the event of war. Such being the case, the great part of the capital sunk in building up our Royal Navy represents merely the premium paid on an insurance policy to protect our food supply. It is then seen that these questions concern the engineering world, and under present circumstances may benefit the ship-building trades; but, on the other hand, supposing agriculture in this country were in a flourishing condition, a larger number of other trades would benefit. One of the grievances of the British farmer is the cost of getting his produce to market, and it is to be hoped that the introduction of light railways in this country will alleviate this to some extent.

It must be conceded that the various inventions and improvements in grain discharging and elevating machinery have benefitted the foreign grain trade considerably, but, at the same time, the use and the improvements in this class of machinery in reality have not been great compared with the growth of the trade. This is attributable to several causes—chiefly to the conservatism of the English people, and also to the peculiar conditions which usually obtain in grain-laden ships. Perhaps the great strike at the Liverpool docks in 1879 did more than anything else to develop improvements in mechanical appliances for discharging grain cargoes. London and Liverpool are the two great centres for the reception of imported grain, and it is to the port which receives the greater amount that one would look for the most perfect appliances; yet this is not the case. Although London imports a greater quantity than Liverpool, yet the latter port has more perfect appliances for discharging grain ships, and also granaries of more modern type.

The author does not intend, in this paper, to advocate any particular appliance or system for working out grain cargoes, but merely to give a general description of the means and methods of doing so, and also to make some remarks on the storage of grain in granaries. It will not be necessary to describe the various sack hoists in use for lifting grain in bags. These are used at warehouses where grain arrives already bagged, or where circumstances do not warrant a larger outlay of capital.

Although there are several different systems and machines for discharging grain from ships, it does not necessarily follow that these appliances, even when obtainable, are made use of. For instance, a ship may arrive with a number of parcels of grain, each parcel being kept apart from the other by matting, which in nearly every case precludes the use of any of the mechanical appliances. Or again, a ship's hold may be divided by longitudinal bulkheads, placed in such a way as to ren-

A BUCKET GRAIN ELEVATOR MADE BY MESSRS. PRIESTMAN BROTHERS, LONDON.

PRIESTMAN BROTHERS' SELF-FILLING AND DISCHARGING GRAIN BUCKETS, FIXED UPON ARMSTRONG HYDRAULIC CRANES.

der this or that system useless in working out a cargo economically. When such cases occur, the method adopted is the primary one, that of bushelling the grain into sacks, hoisting by ship's winch, weighing on deck, and finally backing into the warehouse. In London, a great quantity of the grain coming into the docks has to be discharged over side into lighters, and this method of bushelling by hand is then almost entirely adopted.

The next method of working out a grain cargo to be described is that by means of a crane and a Priestman self-acting bucket or tub, consisting of travelling cranes and hoppers, which are moved into position to command the hatches of the vessel to be unloaded. The buckets or tubs deliver the grain into hoppers, under which are weighing machines. The grain after being weighed drops down through shoots into the warehouse. The cranes, which are generally of the hydraulic type, are capable of making from 60 to 90 lifts of 40 feet per hour, and will each deal with from 50 to 60 tons per hour. The Priestman bucket has the advantage over a tub on account of its being self-filling, but its weight is considerably greater than that of a tub of the same capacity. When dealing with a parcel cargo, the matting separating the parcels is apt to get caught in between the jaws of a Priestman bucket and pulled out of place, in which case a tub is preferable, notwithstanding the extra cost of filling.

One drawback, common to the use of both Priestman bucket and tub, but more especially to the bucket, is the inconvenience in lowering them, caused by the shifting bulkheads, which traverse the length and depth of the hold. The advantages of this system are small initial cost, and by reason of the cranes being movable on the quay, as many hatchways as there are cranes can be dealt with, no matter what the length of the vessel may be, and furthermore, these cranes may be used for discharging grain in sacks, or other goods from a vessel having a mixed cargo.

Of the elevator class of machines there are several types. They may be divided into floating, fixed and portable elevators. Their duty is to dredge the grain from the hold of a ship and to deliver it some 20 feet above the quay. A floating grain elevator of an excellent type designed by Mr. Brice is shown in Fig. 1, and is worthy of being described in detail. The elevator, which is carried on a barge moored alongside the

vessel to be unloaded, is made so as to deliver the grain either on the quay or into barges on either side of the ship. It is self-contained, and carries a boiler and engines for supplying the necessary power. The upright column is double; the inner column is fixed to a heavy foundation plate secured to the deck of the barge or pontoon, whilst the outer column is fixed to another bed plate resting on the lower one, the two being intercepted by friction rollers. By this arrangement the outer column, which carries the horizontal girder, may be revolved in order to suit the position of the ship's hatchway or to house the elevator leg when not in use.

Two pairs of steam engines are fixed upon the revolving bed plate, by which all the motions of the machine are controlled. One pair drives the three winches, and the other, the elevator and conveyors. The horizontal girder, which is made of two H irons, forms a bridge for carrying the elevator trunk, and may be raised or lowered at the long end by means of a winch and wire ropes attached to the short end. The elevator leg is carried in a wrought-iron frame through which it may be moved up or down and follow the level of the grain in the hold; the frame being supported on trunnions, enables it to be oscillated when necessary to move the elevator from one side of the bulkhead or screw tunnel to the other.

In order to allow for the difference in the beams of ships, the frame can be moved longitudinally on the bridge by means of a traverse screw worked by a hand-chain from the deck of the barge. By means of a winch, and with wire ropes attached to the lower end and also to the head of the elevator leg, the leg can be raised from or lowered into the hold of the ship and follow the level of the grain whilst being discharged, or it can be drawn from the vertical position into a horizontal position. Inside the elevator leg are two strands of special endless chain, running over pulleys at the top and bottom of the leg, to which are attached steel buckets.

The driving of the elevator is effected by means of a vertical chain-drive from the engine on the revolving bed plate to the top of the column, and thence by a side shaft and chain-drive to the elevator. A compensating chain-drive is provided on the elevator trunk side, so as to allow the elevator to work in its varied positions without altering the length of the chain. At the top of the elevator head is a telescopic delivery shoot, which delivers the grain upon conveyors; these carry the grain into the warehouse or barge as the case may be. The conveyor is driven and supported by sprocket chain and swivel gear attached to the frame through which the elevator leg slides. The conveyors are made in any convenient length, and consist of an endless band running on rollers between two horizontal plates. Sprocket wheels are attached to each end roller, by one of which the band is driven; the other, if necessary, conveys motion by a chain to the sprocket wheel on the next length of conveyor.

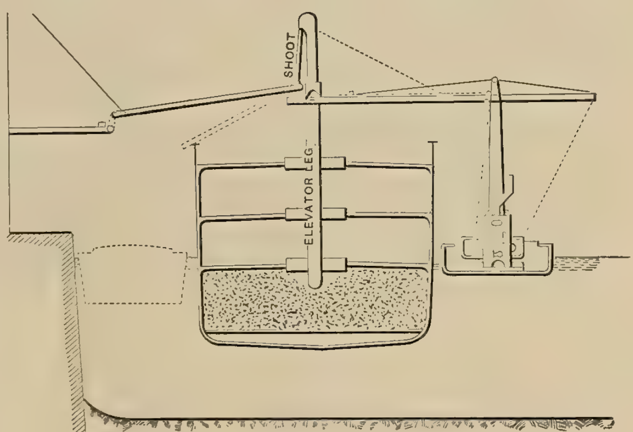


FIG. 1. A FLOATING ELEVATOR.

The distance to which the conveyors can be extended is therefore great. When the cargo is discharged, the

housing of the elevator leg is effected by drawing it up clear of the ship's hatch and laying it on the bridge or jib. The bridge is then swung round until it is fore and aft of the barge, and allowed to fall at one end until it rests on a trestle on the deck of the barge; the whole being made fast, the barge is then ready to be taken to its next destination.

Another type of floating elevator, which is sometimes used in America, not only has an elevator leg and conveyor, but has automatic weighing machines, separators or cleaning machines, and two ordinary elevators arranged in a tower built on a pontoon, so that the operations of cleaning and weighing are performed whilst the grain is in transit. Elevator legs, instead of being mounted on a barge or pontoon, are more often fixed to the wall of a warehouse or in a tower built on a quay. The greater number of these elevators which are to be seen in England are only large enough to deal with grain in barges, but they have been made to unload vessels at the rate of 150 tons per hour. The elevator leg, which simply consists of small buckets attached to belts or sprocket chains running over pulleys or sprocket wheels at top and bottom of the leg, is suspended on a derrick arm which is mounted on a cast-iron bracket attached to the wall of the warehouse or tower. This is shown in Fig. 2.

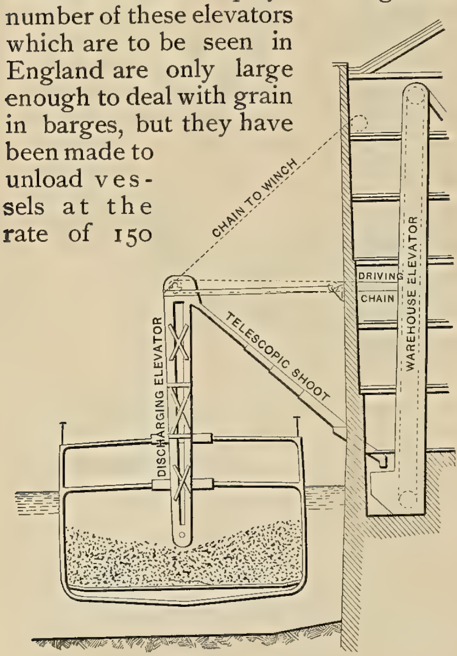


FIG. 2. A FIXED ELEVATOR.

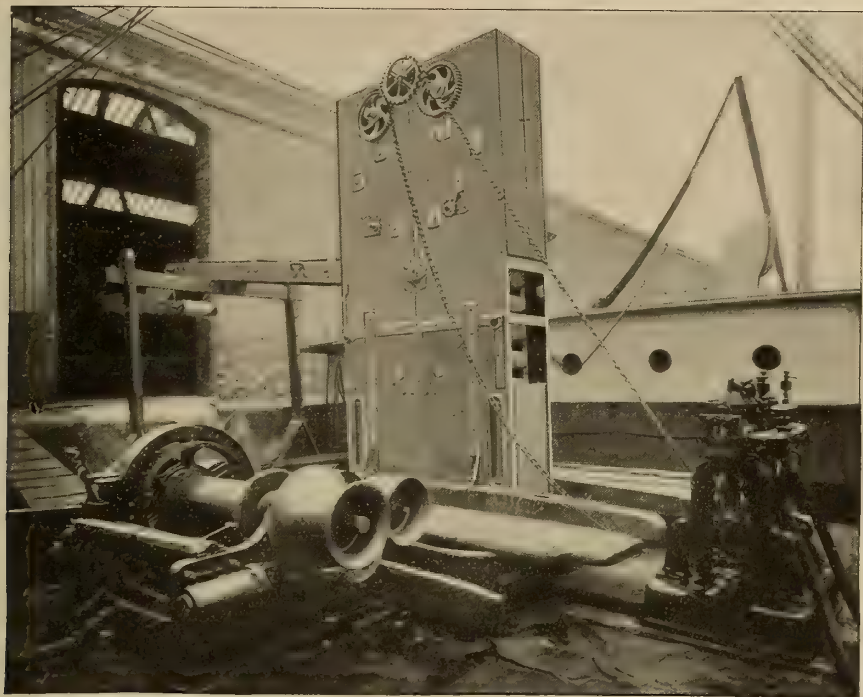
The elevator leg is raised, lowered or completely drawn up and housed against the wall, by means of derrick chains which are worked by a winch inside the building. The grain is delivered by the elevator either into a shoot or on to a conveyor band, which conveys it to a weighing machine. In some cases the bracket which carries the derrick arm, instead of being fixed to the wall, is made so as to slide up or down, and in this way can be made to adapt itself better to the beam of a vessel and also follow the level of the grain as it is being discharged, or, in case of the water being tidal, enables the elevator to perform its duty at any state of the tide.

As already stated, fixed elevators are sometimes suspended from a tower built on the quay, the warehouse itself being situated some distance from the latter. Inside the tower are weighing machines and an engine for working the elevator. The grain, after being raised to the top of the tower, passes through a weighing machine and is then delivered upon the band conveyor in a subway under the quay which communicates with the warehouse. The dust in the warehouse, caused by handling the grain, is thus reduced to a minimum, by reason of the weighing operations being conducted in the tower away from the main building.

Another form of elevator very similar to the previous is of the balanced girder type (Fig. 3). In this case the elevator leg is hung from one end of a girder; trunnions are attached to the sides of the girder, and rest in bearings on a movable carriage, and the other end of the girder is counter-weighted in order to compensate for the weight of the elevator leg. The carriage is moved backwards or forwards to place the elevator leg over the ship's hold, whilst the girder is caused to rotate to raise or lower the leg. These elevators (Figs. 2 and 3) and their modifications, are especially adapted for working out grain in bulk from barges.

Portable grain elevators for discharging ocean-going steamers have increased

in number of late years. On the Mersey alone there are some fifteen portable elevators made by Messrs. S. S. Stott & Co., whilst others may be seen at Glasgow, Antwerp, Marseilles and other ports. They are all designed so as to be carried from ship to ship, as shown in Fig. 4. This elevator consists of two long wooden trunks. Each trunk is provided with a leg which acts telescopically, and automatically lowers itself by its own weight into the grain. Grain buckets on sprocket chains run over a wheel at the bottom of the telescopic leg and round another wheel at the top of the trunk. A compensating arrangement for the bucket chain is provided inside the trunk to allow the leg to fall without interfering with the working of the elevator. Each trunk, with its leg, can be worked independently. They are lifted and placed in the ship's hold, and are carried by two beams placed across the hatchway.



PORTABLE SHIP-DISCHARGING ELEVATOR MADE BY MESSRS. S. S. STOTT & CO., HASLINGDEN, ENGLAND.

The motive power is generally derived from an engine placed upon the deck of the ship, steam being supplied by means of a flexible hose from a boiler carried on the elevator barge. An elevator, 28 feet in length, will unload a steamer 40 feet deep, and deliver the grain 15 feet above the quay at the rate of about 60 tons per hour. The machine is light, and the whole apparatus can be lifted on to the deck, fixed in the ship's hold, and started in one hour, provided that the ship possesses a suitable boom or jib by which the trunk can be lifted. The first cost of these machines compares favourably with other grain-discharging elevators, and the machine being practically duplex, the grain is taken from each side of the screw tunnel and the vessel kept in even trim. By stopping the working of one leg a list of the ship can be corrected, should it occur. It will be noticed that the grain is carried to the top of the leg and there delivered to the conveyors, but a later machine built by Messrs. Stott &

Co. consists of a single trunk, and delivers the grain in its upward journey at any point required, by the buckets being reversed by means of a pair of rollers.

On the Continent, travelling elevators may be seen which run on a broad gauge track and have a high overhanging platform, from one end of which a telescopic tube with bucket elevator leg hangs, and at the other a telescopic shoot. Fig. 5 shows a travelling elevator of somewhat similar type, but this is much smaller and designed for unloading barges only. It will be seen that it runs on rails, and overhangs on one side only, and in this respect it differs from the larger types used for discharging ocean-going vessels. The body of the machine is made to rotate on rollers running on a race fixed to the frame of the under-carriage. The elevator leg consists of telescopic tubes which are lowered to suit the varying water levels or follow the level of the grain. The weight of the sliding tubes is partly balanced by counterweights at the back of the machine.

Special arrangement has to be made in order to allow the telescopic tubes to be lowered or lifted without interfering with the working of the elevator. This is accomplished by the endless elevator belt or chain, as the case may be, running not only over the top and bottom pulleys of the elevator leg, but also around other pulleys or sprocket wheels, mounted on a movable carriage which can be moved to or from the leg. When the tubes are up, the carriage is at the back of the machine; by moving the carriage forward any distance, the telescopic tubes are lowered double that distance. If the buckets are attached to belts, instead of chains, the belt has

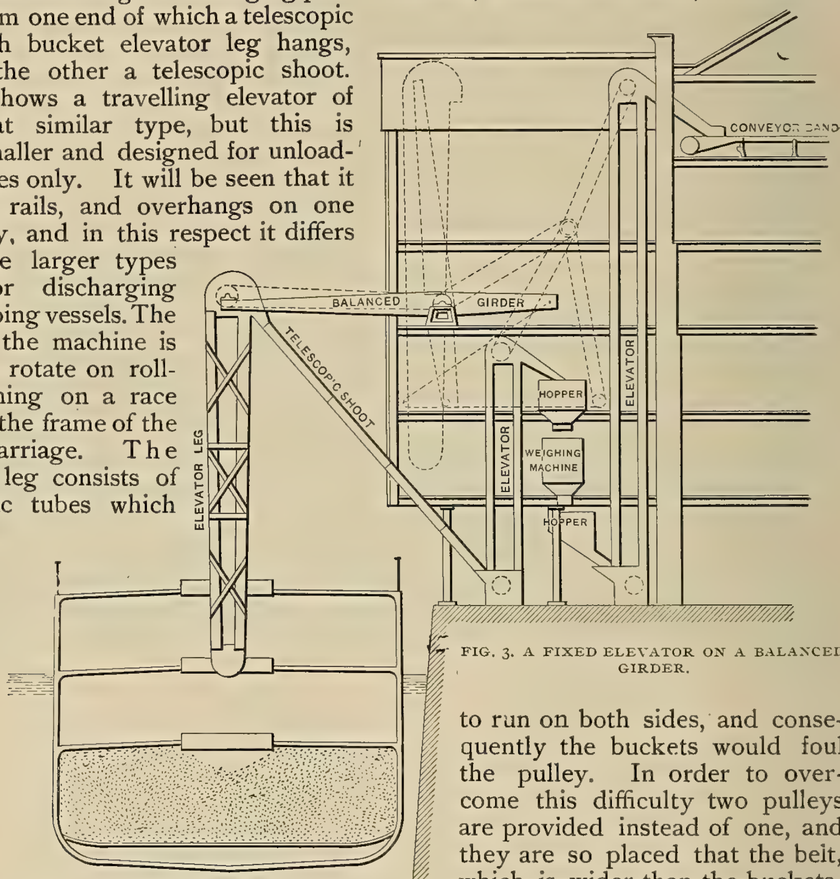


FIG. 3. A FIXED ELEVATOR ON A BALANCED GIRDER.

to run on both sides, and consequently the buckets would foul the pulley. In order to overcome this difficulty two pulleys are provided instead of one, and they are so placed that the belt, which is wider than the buckets, runs with its free edges on the pulleys, thus allowing the buckets to pass between them. Running along the top of the elevator carriage is a conveyor band for carrying the grain, after it has been raised by the elevator buckets to the weighing machine. Thence it is either delivered into sacks, or passes down on to a carrying band in a subway, which conveys it to its destination. This type of machine often carries its own engine and boiler, or derives its motive power from a hydraulic main.

For many years past much attention

has been bestowed on means whereby grain can be raised by compressed air or by suction. Many difficulties have had to be overcome, difficulties which at one time appeared almost insurmountable, but the two pneumatic elevators which are to be seen in the port of London demonstrate that the system is practicable. The Atmospheric Grain Elevator Company's system of raising grain, which was tried a few years ago, was to direct a continuous stream of compressed air, at a pressure of about 40 pounds, through a nozzle of special construction up a flexible pipe which acted as a conduit for the grain. By the force of the air current the grain was carried along the pipe to its destination. The grain pipes were made of India rubber, strongly bound with wire to prevent the rubber expanding. By this system grain can be raised economically to a limited height, and for that reason it should be used only for lifting grain from a ship into barges, or into a hopper standing not too high on a quay, the grain being conveyed, if necessary, to the top of the granary by an ordinary bucket elevator. This latter remark applies equally to the system of raising grain by suction.

A pneumatic grain elevator was built for the Millwall Docks a few years ago. The plant was designed by Mr. F. E. Duckham, the engineer to the Millwall Docks Company, and consists of an air-exhausting engine and three pairs of grain tanks and weighing machines erected on a pontoon. A vacuum is formed in the grain tanks from which flexible grain pipes pass to the ship's hold. The air, passing up the pipes to fill the vacuum in the tank, carries the grain with it; there the grain falls to the bottom of the tank, the air being drawn out through the top of the tank. At the bottom is an outlet through which the grain passes into one of two receptacles, which, as it gets filled, falls by its own weight and brings the other receptacle under the outlet in a position to be filled; meanwhile the full receptacle, being out of communication with the vacuum, opens automatically and discharges the grain into a hopper, when it is weighed and delivered into barges. (Fig. 6.)

This plant would be more economically erected in a granary, thereby saving the cost of the pontoon, but in that case the grain could be delivered only in the warehouse where the vacuum tanks are, and not into barges. The grain pipes were 6 inches in diameter, made of rubber with an inside lining of wire to prevent collapsing when the vacuum, which is from 2 to 5 pounds per square inch, is created inside them. The rubbing action of the grain in mo-

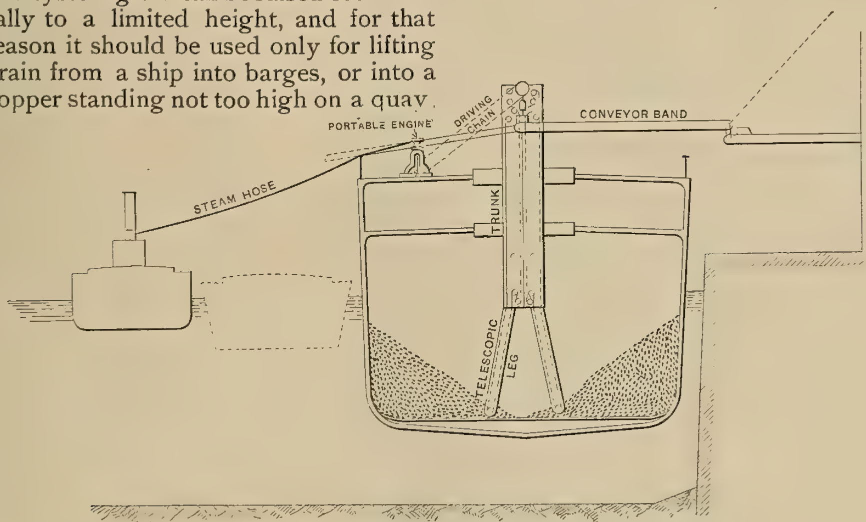


FIG. 4. A PORTABLE ELEVATOR

tion, to which these pipes were subjected, was so severe that it became necessary to devise some form of pipe which would stand this wear. The pipes now in use consist of a number of steel conical cylinders strung together in such a way as to be flexible, and encased in rubber to make them air-tight (Fig. 7). The nozzle at the end of the suction pipe is of a special design, which allows a supply of air to be drawn up with the grain.

The power required to drive the air exhausting or air-compressing engines of these pneumatic elevators is far greater than the power required merely to lift the grain in bucket elevators; and furthermore, in horizontal pipe lines the grain has a tendency to fall to the bottom, whence it is difficult to remove it by a current of air, and for this purpose more power again is required. The advantages of these two pneumatic systems are that only one man is required to look after each nozzle; no trimming of the grain is required, as the nozzle can be directed into any corner or crevice; the pipes occupy comparatively no area of the open hatchway; the hatchways may be covered by tarpaulins in wet weather without interfering with the operation of discharging the grain; and efficiency in discharging is secured, each pipe being capable of lifting from 30 to 40 tons of grain per hour.

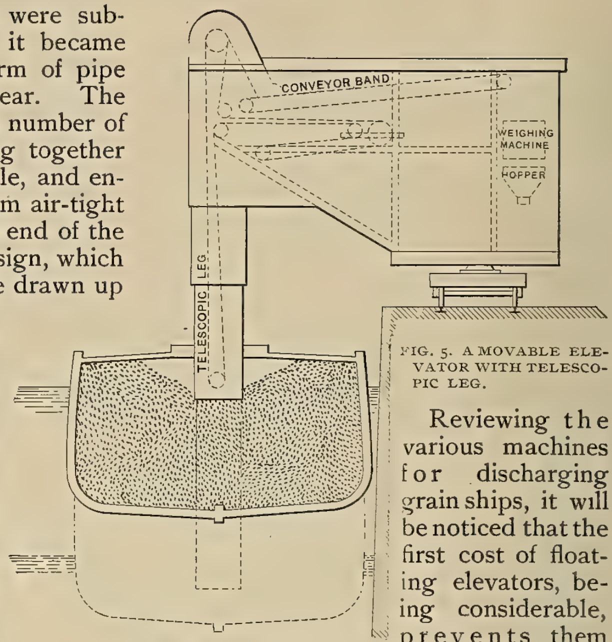


FIG. 5. A MOVABLE ELEVATOR WITH TELESCOPIC LEG.

Reviewing the various machines for discharging grain ships, it will be noticed that the first cost of floating elevators, being considerable, prevents them from being extensively adopted. Again, the price of fixed elevators is low, but, as the author has pointed out, two or three fixed elevators cannot always be in positions to command hatchways, and therefore, perhaps, one or two must remain idle. However, when grain arrives in barges, the despatch required in the

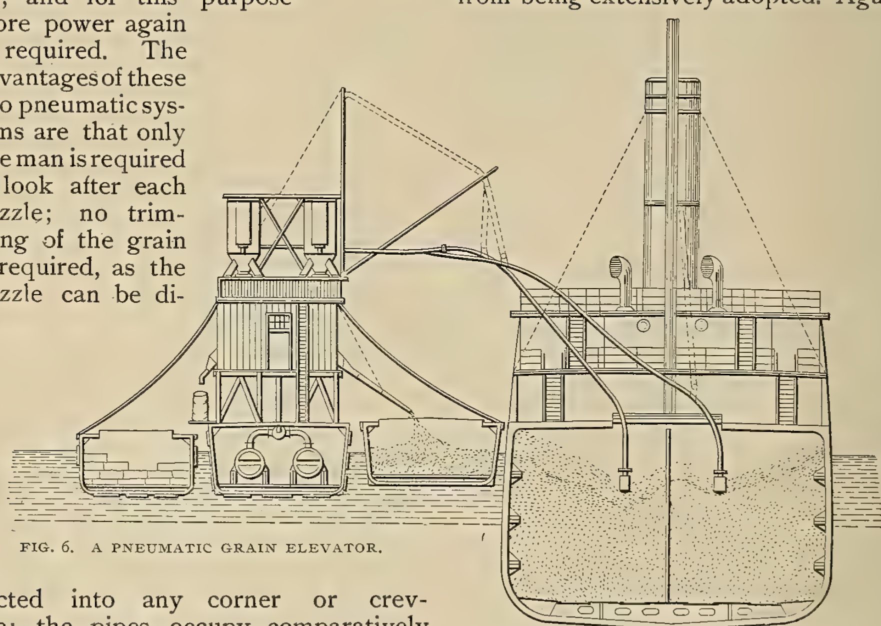


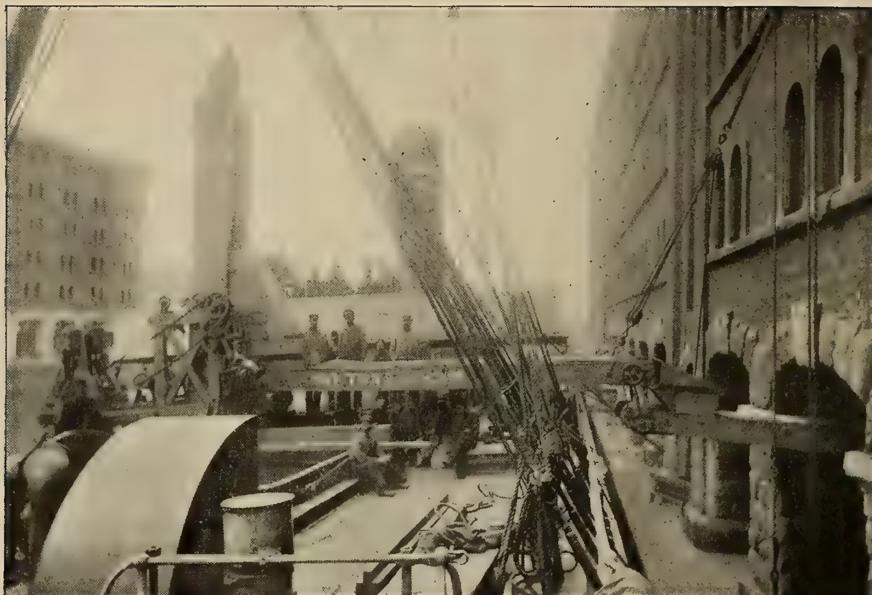
FIG. 6. A PNEUMATIC GRAIN ELEVATOR.

case of steamships is not necessary, and in that case one fixed elevator is sufficient. The portable and movable elevators, and also the movable crane and bucket systems, overcome the difficulty of not commanding the ship's hatchways. The first cost of these three types of machines and the cost of lifting grain are much the same in each case. The advantage of the crane and bucket over the other two is that the crane can be used for discharging any other kind of merchandise, and with a Priestman bucket less trimming of the grain is required than with an ordinary elevator leg.

Perhaps the greatest inconvenience is found with the shifting bulkheads which are necessary in a grain ship (in fact, not enough use is made of them to minimise the risk of grain cargoes shifting), in interfering seriously with the rapid discharge. The initial cost of compressed air and suction systems of discharging grain is great, and moreover, in the latter case, as at present designed, it is not capable of delivering grain both into a granary and a barge. An advantage which no other system has is that trimming in the ship's hold is dispensed with. However, with the ordinary elevators, trimming shovels are often used. These consist merely of a rectangular board about 4 feet 6 inches by 2 feet 6 inches, to which a rope is attached and led through pulley blocks to a winch with an alternate reversing motion, which draws the shovels in a fore and aft direction alternately.

Having described the various means for discharging grain from ships, the author will now describe the usual appliances and means of conveying and distributing grain in granaries. A few remarks, however, should first be made concerning floor granaries and granaries built on the silo or bin principle. In America the floor granary is the exception rather than the rule, but there grain is classified or graded, and the granary, or grain elevator as it is called in that country, may be said to be like a discount bank. Grain may be deposited at Chicago one day, and the next day the same quantity and quality may be drawn at New York. In this country little has been done in the way of silo building; perhaps this is due to the conservatism of Englishmen, and also to the fact that dock companies and other authorities often receive a number of small parcels of grain, and, there being no universal classification, this necessitates the storing of each cargo separately.

A PNEUMATIC GRAIN NOZZLE.



ANOTHER FORM OF PORTABLE CONVEYOR MADE BY MESSRS. S. S. STOTT & CO.

The advantages of the silo system are: freedom from the risk of fire, greater storage capacity on a given area of ground, economy in building, economy in handling the grain when delivering into sacks, railway wagons or carts, and also economy in turning over grain for ventilation. The ventilation or turning of grain is accomplished by discharging it from the bottom of the silo and conveying it up an elevator back into the same silo, or (better) into another silo. Another altogether different system of ventilating is to provide the silos or bins with two bottoms, the upper one having a number of holes through which a strong current of air is forced, which passes through the grain to the top, thereby cooling it and bringing it into better condition.

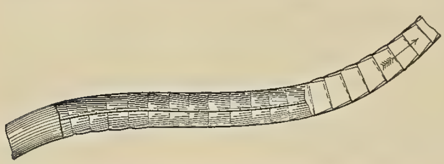


FIG. 7. STEEL PIPE FOR PNEUMATIC GRAIN ELEVATOR.

The economy in building a silo granary is apparent when it is considered that very nearly the whole capacity of a silo granary is used; but in the case of a floor granary a great amount of the space between the floors is wasted, or, to put the case in figures, the storage capacity of a silo granary to that of a floor granary is three to one. Sections of a typical silo granary are shown in Fig. 9. Silos are built either of timber, iron, brick, or of iron framework filled up with cement. Timber silos are light and strong; they are bad conductors of heat, and are capable of imbibing moisture from the grain; which are advantages. The objections to timber as a building material are its inflammability; it is subject to dry-rot; and it is not easy to renew a defective part. Iron, in the form of sheets, as a material for building silos, is advantageously used for cylindrical bins, whereby stability and safety from fire are obtained. The disadvantages of iron are that it is a good conductor of heat, and therefore, should the grain get hot in one bin, the surrounding bins are soon affected; also, it does not imbibe the moisture of the grain which condenses on the sides of the silos, and thereby spoils the grain

coming in contact with it. Brickwork is a good material to withstand fire, and takes up moisture to a certain extent; but the walls have, of necessity, to be rather thick to insure stability, and so they take up space. Sometimes partition walls are made of iron framing with wirework filled in with cement. Such walls possess the advantages of brickwork, but do not imbibe moisture to the same extent.

The form of silos in plan is either circular, square or hexagonal; the shape adopted should be governed by stability, utilisation of space, and material of which it is constructed. The hexagonal is perhaps the most common when brick or cement is the material used; square when of timber. Another consideration in the design of a bin is the form of its bottom. The most usual forms are the pyramidal or conical, although they have the disadvantage of not discharging the grain which lies in the angle formed by the walls and the base of the bin, and so, when turning the grain into the same bin, in order to ventilate it, a quantity of grain is never turned at all. Another plan is to make the base horizontal, with several outlets.

By far the greater number of granaries in the United Kingdom are built on the story and post plan, the average distance between the floors being about 9 feet. In order to keep the grain in good condition, heavy grain is laid in heaps, usually not more than from 3 to 4 feet high, and light grain from 5 to 6 feet. This necessitates a great waste of storing space, and in addition to this waste the heaps have to be separated by gangways, in order to keep various consignments apart. In order to preserve grain and ventilate it, a permanent draught is insured by such buildings being provided with a large number of windows. Grain in these warehouses is usually turned by hand if heating occurs; but a warehouse may easily be designed to ventilate the grain, as in the case of silos, by means of conveying machinery and shoots. These granaries are often used for other purposes, and for storing grain in bags, which advantage is not to be had in a silo granary.

There is another system of storing grain, which, so far as the author can learn, is in use only at the Millwall Docks, London. The system in vogue there is to store grain in specially constructed trucks or wagons, somewhat similar to open railway trucks. These bins or wagons are covered with tarpaulins, which are laid over a cross bar between the two ends of the truck. At the sides of the wagon are holes through which delivery of grain is made. The trucks, when full, hold about 20 tons of grain, and are run on to sidings or under sheds. When delivery is required to be made, the trucks are run on to a siding, alongside which runs a railed road on a lower level, which allows a sufficient height for the grain to be discharged into sacks on a weighing machine or into another railway wagon.

This system of storing grain in movable bins enables the delivery and receipt of grain to be made at any convenient siding in the docks, instead of being confined to the limited space round a granary; but it must be remembered that the trucks cover a very large area of ground compared with that of a granary. Roughly speaking, a silo granary will store 5.25 quarters of grain per square foot of ground covered; a floor granary 1.75 quarters; whilst a grain truck will only store 0.75 quarters per square foot. The cost of a silo granary may be taken as 6s. 6d. per quarter of storage capacity, that of a floor granary 13s. per quarter, whilst that of a grain wagon will be 8s. per quarter, exclusive of ground rent.

The machinery and appliances used for conveying and distributing grain in granaries are much the same, whether they are built on the silo or the floor system. The grain, after being discharged from the ship, is weighed and conveyed to the foot of an elevator fitted up inside the warehouse. These elevators (of which there are two or three, according to the size of the granary) are similar to the leg of a discharging elevator. Each elevator extends from the bottom to the top of the granary. It consists of an endless belt or chain, provided with dredger buckets running

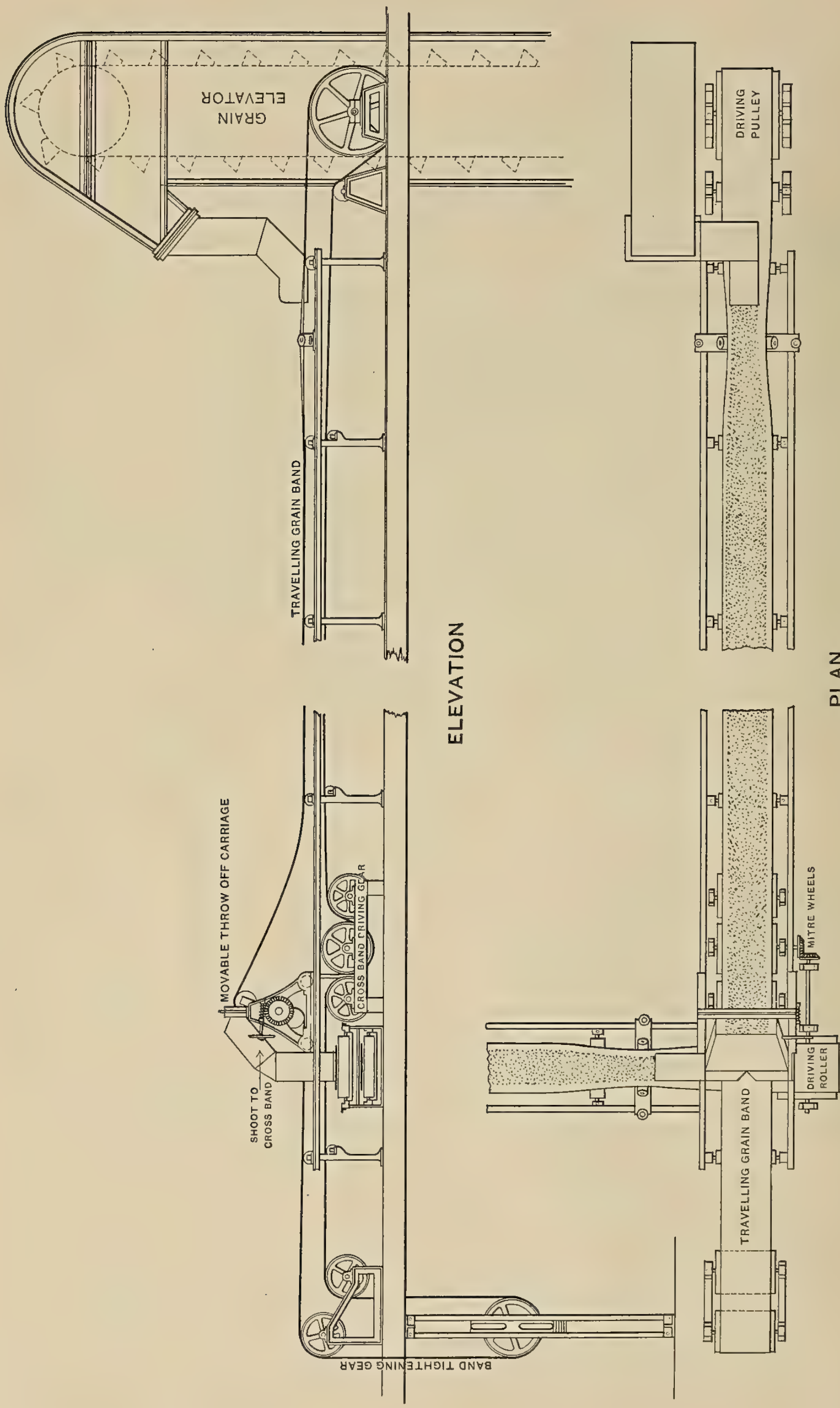


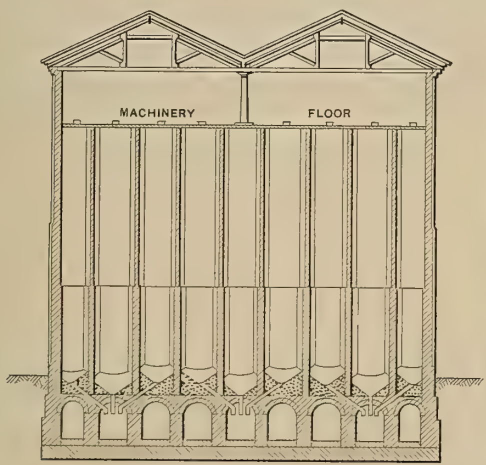
FIG. 8. GRAIN CONVEYOR BAND AND GEAR.

over pulleys in bearings in the bottom boot and head of the elevator leg.

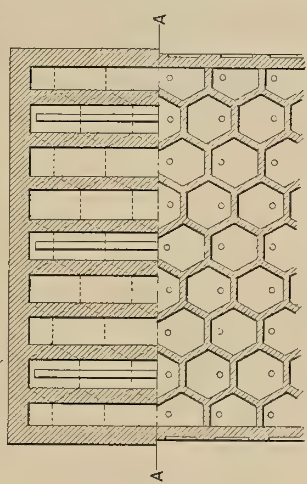
The connection between the bottom boot and head is made by a case of iron or well-seasoned pine, which incloses the belt. The boot and head are generally made with cast-iron sides and a steel bottom, the boot being fitted with a tension arrangement to take up any slack that may occur in the belt or chain. When large elevator buckets are used, a double-strand chain is adopted in place of a single. These chains are claimed to be cheaper, more durable, and do not stretch like India rubber belts. Elevators should be driven at the top, as all the weight of the band and buckets is on the top pulley, and therefore the band has not the same tendency to slip on the pulley as it would if the lower one were driven.

The grain having been raised to the top of the granary, if it has not already been weighed will be so now, and distributed or conveyed to that part of the granary where it is to be stored. The general arrangement and size of the granary will decide how this distribution of the grain can best be effected. Conveyor bands for distributing the grain are sometimes dispensed with, in which case the grain is delivered by the elevator into shoots, which diverge in all directions to the floors or silos of the granary. This arrangement, in a large granary, requires a number of elevators, and also causes a waste of head room in order to give sufficient depth to shoot the grain into the different bins or on to the granary floors. However, this is often done in a silo granary, one elevator commanding some dozen bins or so. When it is desirable to keep down the height of a building, conveyor bands are used which run the whole length and breadth of the granary in directions at right angles to one another. Worm conveyors are seldom used, except where the grain has to be only carried a short distance, as the amount of power required to work a worm conveyor compared with that required for a travelling band is much greater. A conveyor-band which is illustrated in Fig. 8, is simply an open belt drive on which the grain is carried, and is made of cotton canvas and India rubber. The width of a band varies from 10 to 36 inches, according to the amount of grain to be carried. A band of 18 inches width, travelling at the rate of 8 feet per second, will carry about 70 tons of heavy grain per hour.

The bands are made continuous, and both the carrying and the free side of the band have to be supported by



VERTICAL SECTION ALONG *A A*.



SECTIONAL PLAN.

FIG. 9. A SILO GRANARY.

DELIVERING GRAIN TO STORAGE SHEDS BY BAND CONVEYORS.

wooden or steel cylindrical rollers in bearings fixed on cast-iron frames, which are made in many forms, to be either laid on a floor or suspended from a joist. Rollers are placed about 6 feet apart under the carrying side of the band, and double that distance apart under the free side. Comparing steel rollers with wooden rollers, those of steel are superior in every way, being lighter, more durable, and not liable to crack or warp as the former are. As regards expense, steel rollers are a little more expensive than those of wood. In addition to these rollers, oblique side rollers are used in order to trough the band where the feed comes on, and thereby prevent the grain from spreading. These are also found necessary at intervals where it is required to carry grain any great distance. To ensure the proper working of a band, a self-tightening apparatus must be provided to take up the slack in the band, and it is generally found convenient to place this at one end of the drive. One form of tightening gear is shown in Fig. 8; it is most efficient, and is capable of taking up any variation, and may be placed anywhere along the band. To transfer grain from one band to another running at right angles to it, a throw-off carriage is used. One form of these machines is seen in Fig. 8; the object is to give the conveyor-band an upward deflection by running the band over a roller above the general level, and then under another roller placed below the former. The grain is thus cast clear of the main band, received in a hopper, and passes through a spout which has an inclination of about 45 degrees, so as to give the grain a velocity nearly equal to that of the cross band on which it is deposited.

The throw-off carriage illustrated in Fig. 8 is constructed so as to throw off the grain with the conveyor-band running in either direction, or to carry the grain forward between the rollers. The machine consists of two wrought-iron rollers mounted in gun-metal bearings on an arm which is made to revolve on a movable carriage. The revolving arm is rotated in either direction by means of a screw and worm-wheel, which brings the rollers into a position for throwing off the grain. The carriage is mounted on small wheels and runs on angle irons or rails fixed to the top of

the roller frames; it can be moved to any position where it is required to throw off grain from the band. The cross bands are sometimes driven from off the lower free half of the main band by means of a roller, the motion from this roller being communicated to the cross band by means of a pair of mitre wheels; but where the bands are of considerable length, it is preferable to drive them by separate engines or independently of each other.

THE CITY OF THE FUTURE.

By E. H. Mullin.

LORD KELVIN, while at Niaggara Falls during his recent visit to the United States, made a pregnant remark about what the Falls of Foyre in Scotland would do for the Highland peasantry when their energy, now going to waste, was converted into electricity and distributed to the surrounding cottages.

"It will give life and prosperity to the Scottish Highlands," said Lord Kelvin, "and give the people cottage industries instead of having them act as guides and posters for tourists."

We, of this generation, in our self-sufficiency, are too apt to forget that all the concentration of cities and manufactories which has characterized the last half century, rests like an inverted pyramid upon a steam cylinder. Before the era of Watt and Arkwright every cottage in England worthy of the name had its hand loom and its spinning wheel. Either the small farmer and his family spun and wove in their spare time or the weaver and his family cultivated a small farm in their spare time. In either case nothing was to be gained by leaving the open country or small village for the great cities, as long as the market town with its weekly sales and purchases of homespun at supply and demand rate was within reach.

Even after the power loom and the spinning frame, driven by steam engines, had begun to segregate workmen and their families near the steam cylinder, another difficulty arose which was surmounted only a generation later by the introduction of the steam locomotive. It was easy enough to gather people together close to the steam plant, but every town and city in the United Kingdom, including London itself, had previously lived off the farm produce raised in the surrounding country, within a radius of fifteen miles at the most.

Thus the power loom gradually destroyed the hand loom—the symbol of cottage industries—before the means of feeding the new industrial army which concentrated about the steam engine were fully understood. Much of the misery, in fact, which marked the transformation of hand work into power work, and which we remember now under the general terms of Luddite riots and the Chartist movement, was due to the high price of provisions in the factory districts before wages had advanced sufficiently to cover the difference between the old conditions and the new.

Then, after some delay, came the locomotive with its cheap freight. This allowed the North of England to become one huge factory district, while the Southern part of the country became the farm which supplied the aggregation of factory towns with flour and beef. Still, as we see, everything depended on a steam cylinder; the factory hands concentrated to be near one kind of steam engine, and dependant upon another kind of steam engine for their daily supply of cheap provisions.

Then came the great steamship movement with which we are all so familiar to-day, when every two pounds of coal burned meant a horse-power developed for an hour, when the cost of freight and insurance for wheat from New York to Liverpool was lowered to 4d. a bushel or less, when the great Western American prairies, which had been lying ten thousand years fallow, were merely scratched on the surface to bring forth thirty bushels of wheat to the acre for fifteen or sixteen consecutive years.

Meanwhile, cheap freights having practically equalised the price of provisions throughout the civilised portion of the globe, the last impediment to industrial concentration was removed, and cities favourably situated with respect to coal—that is, raw steam power—increased in population far beyond the wildest conjectures of our grandfathers. Yet while the industrial masses were better housed and fed, under this new regime, than ever before, the broader and deeper results were not wholly satisfactory.

Concentration for work meant concentration for living as well; the hardy, healthy childhood of the country was badly exchanged for the air starvation, tenement-house squalor and multiplied temptations of the cities, until it became, and still remains, a question with many sociologists whether the industrial concentration in the cities was not calculated to bring about its own downfall by completely absorbing the energy of the individual city units, at first reducing and ultimately destroying the fertility of the race. Just, however, as the evils that steam was likely to bring about were becoming distressingly apparent, a cloud, at first no bigger than a man's hand, appeared on the horizon and has since been spreading until it promises to eclipse steam almost entirely as the prime mover in industrial enterprise.

Electricity, unlike steam, can be distributed over a wide area from the point of its production, with comparatively little loss; unlike steam, it can be stored up for an indefinite length of time, ready for instant use; unlike steam, it can be economically sub-divided into units small enough to run a sewing machine. Thus electricity, as a motive power, permits dispersion of the industrial population where the defects of steam made concentration an absolute economic necessity. Moreover, so far as the waterfalls of the world are to be utilised for the production of electricity, they will invite the establishment of industrial works under new conditions and with new surroundings.

Lord Kelvin, on the occasion previously referred to, spoke of the economical industrial radius of the electricity produced by the Falls of Niagara as 40 miles. While the limit of the concession of the Cataract Construction Company was 450,000 horse-power, Lord Kelvin said he hoped that our children's children would see no Falls at all, all the water—equal to 7,000,000 horse-power, according to Prof. Unwin—being applied to industrial uses. But a radius of 40 miles is equal to an area two hundred and thirty-three times the size of Manhattan Island, for example,

on which the city of New York now stands, so that the Niagara Falls industrial district is capable of supporting a population of 58,000,000 before reaching half the density of the population on Manhattan Island. And if the whole 7,000,000 horse-power of the Falls be taken, a previous calculation, made by Lord Kelvin, shows that the electricity thus produced could be distributed over a radius of 150 miles at a pressure of 80,000 volts, with a transmission loss of only 20 per cent. But the area of 150 miles radius is to the area of 40 miles radius in about the proportion of 14 to 1; therefore the larger circle would support, at the rate of half the density of Manhattan Island, the almost incredible population of 812,000,000, or about two-thirds the population of the entire globe.

Were Niagara the only great waterfall in the world, it is quite possible that these figures, or something like them, might be realised, because long before the world's coal supply is exhausted, its price for steam-raising will be prohibitive, while as long as the sun shines the waters which fall into the ocean will be lifted up and carried back to the Great American Lakes. But between Niagara Falls and tide water, there are now under construction works to take 150,000 horse-power from the St. Lawrence River at the Long Sault rapids, without perceptible diminution of the river's flow through the main channel. The city of Montreal is now getting light and power from the Lachine Rapids, also on the St. Lawrence River, and it may be that the same particle of water will help first to turn the turbine at Niagara, then the turbine at Massena, near the Long Sault, then the turbine at Lachine, while a pound of coal burnt at Niagara is gone forever.

It has already been remarked that the modern industrial city has been dependent for its rapid expansion upon its superior advantages with respect to coal—that is, it must have either a navigable water front, or be a natural railway receiving and distributing centre, or be the natural focus of a coal and iron region. All this will be changed in the great electrical waterfall cities of the future. The power, as a rule, will be produced in the mountains, while the cities will be scattered far and wide over the foothills. There will be better air, more room, better drainage, more civilised conditions of living than is the case with the present overcrowded industrial bee-hives, built, for the most part, on the swampy deltas or in the valleys of great rivers.

Under the pressure of dear coal and with the attraction of cheap water power, the face of Europe will be changed. As indicated by Lord Kelvin, the Highlands of Scotland will become industrially more important to Great Britain than the comparatively flat Midlands. Switzerland, Norway and Sweden, the Austrian Tyrol, and Transylvania may become the industrial centres of Europe owing to their superiority in water power. For the rest, the course of manufactures will seek the sources of the great rivers, or of rivers not great which have a very rapid fall.

Thus, in the United States, Montana, containing, as it does, the stormy beginnings of the Missouri, is already developing as the greatest ore-refining region in the world. Utah and California, in both of which coal is $5 a ton and upwards, have now horse-power to spare for industrial purposes from the waterfall electric plants which they already have in operation. Portland, the capital of Oregon, now gets its light and power from turbines on the Columbia River. Colorado, a year ago, had seventeen different electric plants, driven by water power, used exclusively for mining purposes. The State of Washington and the whole Dominion of Canada have waterfalls without end which have as yet hardly had their possibilities of creating electrical energy estimated.

In more distant lands we find English engineers already making plans for saving the energy of the falls of the Nile fifteen miles below Cairo, and it is well within the bounds of probability that the Nile cataracts will some day supply the power necessary for running trains of cars from Alexandria to Khartoum. Not only are there magnificent falls on the

Zambesi itself, in South Central Africa, but many of its branches in the Shiré Highlands have rapid descents in level, admirably suited for the development of electricity by turbine wheels.

We too often think of Hindustan as a great plain, forgetting that the Himalaya Mountains, the highest on the globe, give birth to the Ganges, the Indus, the Brahmaputra and the Oxus, all of which, with their mountain tributaries, reach the plains after taking innumerable giant leaps down the mountain sides. It is nonsense to say that the development of this water power is visionary; the Falls of the Zambesi are much more within the range of civilisation to-day than any part of Montana, for example, in the United States, was thirty years ago.

There are bankers in Bombay, Parsees at that, who have as much capital and as much nerve in investing it as the greatest men in the financial centres of Europe and America. The cheapness of ocean freights has equalised the price of wheat and beef at every seaport in the world; the invention of automatic, labour saving machinery has made the Hindoo or Japanese, standing at a loom, very nearly the equal of the American or Englishman doing the same work. And as invention along the older lines of human effort makes progress in machinery from less automatic to more automatic, so will the natives of Hindustan and Africa be able, under Caucasian direction, to utilise all the natural and local sources of power which Providence, through the sun's evaporative agency, has provided for them.

THE COMPOUND LOCOMOTIVE IN THE UNITED STATES.

By William Ledyard Cathcart.

OFFICIAL statistics give the total number of locomotives in the United States as, approximately, 36,000. These are, almost wholly, of the single-expansion type, the compound, or double-expansion, having won its way, thus far, in but small degree. Assuming, for each engine, the rather low annual mileage of 35,000, with a consequent coal consumption of about 2500 tons, we have a total consumption of 90,000,000 tons per year. If this coal average in cost, on the tender, $2.25 (9s.) per ton,—a price which does not seem excessive when the entire country is to be considered,—the annual expenditure for fuel will be $202,500,000 (£40,500,000).

Tests of many kinds, and the records of continuous service over long periods, show an average saving of fuel, through the use of the double-expansion or compound locomotive, of fully 20 per cent. If, then, the engines of this system are, for all railroad service, practicable mechanisms, and if they shall supersede all others in the United States, there will be a saving annually of $40,500,000 (£8,100,000), — a great sum which, if these premises be admitted, vanishes yearly in steam, whose expansive power has not been utilised fully, and in fuel, whose combustion is incomplete and which, as flying sparks, leaves too often in its wake a trail of flame and of further financial loss.

In reviewing this, one needs but scant imagination to picture the angry wraith of Hornblower, the inventor of the double-cylinder engine, hovering in the sooty clouds above American railroads, or the melancholy figure of Woolf, the originator of the compound condensing engine, listening, almost in vain, amid the hoarse chorus of exhaust from the army of single-expansion locomotives, for the soft sighing of the lonely and infrequent compound.

A technical journal, in commenting on the proceedings of a recent convention of railroad men, has said:—

"The testimony of the speakers was that compound locomotives saved from 15 to 25 per cent. of the fuel required by a simple engine to do the same work, and that the expense for repairs was not materially different. Now, in view of all this, it is passing strange that railroad companies are not running their shops, day and night, with a full force of men engaged in changing their locomotives into compounds."

The picture seems more sombre still when we note the swift progress of steam in marine machinery. The ceaseless demand upon designers for greater speed and sea-keeping power, while still reserving adequate tonnage for cargo or for armament and armour, has forced higher pressures and multiple expansion. Passing, long since, from the single engine, the compound stage has been reached and left behind, and triple and quadruple expansions now rule.

With but few exceptions the war-ships of the new fleet of the United States are equipped with triple expansion machinery. In the merchant-service, the American-built *St. Louis* and *St. Paul*, the magnificent steamers of the International Navigation Company, have quadruple expansion engines of 20,000 horse-power. And, in British waters, the phenomenal *Turbinia* has reached

the greatest speed ever known at sea, through the driving power of three sets of parallel-flow steam-turbines, working in series, and expanding steam from 170 pounds absolute to one pound absolute, at which pressure it is condensed.

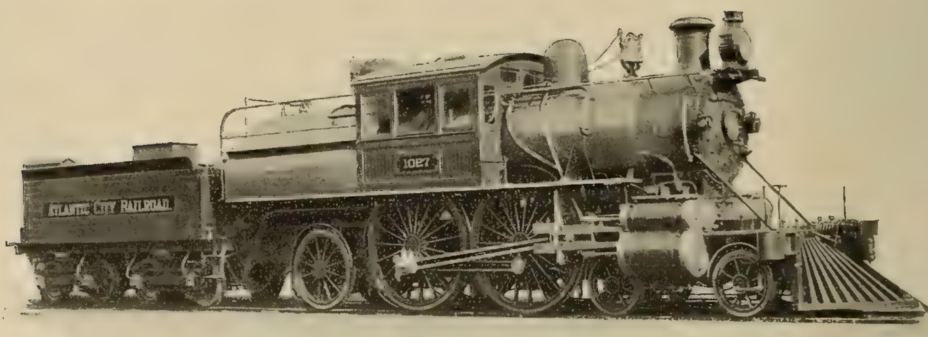
Recently an able writer, in describing a triple expansion engine of 2000 horse-power, built for one of the largest textile manufacturing companies of the United States, said;—

"About the same time (1876) marine steam engineering, which, of necessity, has always been the leader in improvements, had fully demonstrated the economy of higher pressures and multiple expansion; and stationary engine builders were not long in following suit."

It would seem, then, that, except in railroad service, engines of double and triple expansion have met full recognition, although but brief study of their history will show that this recognition was won only after years of opposition, argument and elaborate testing.

In considering the attitude—waiting, as yet—of railroad management toward multiple expansion, there would seem to be but one of three main reasons to explain it:—Either the traditional American ingenuity has failed to grasp an opportunity so great, and the compound locomotive is not, as yet, an engine fitted fully for railroad service; or, those in authority have disregarded wilfully the economy which is possible through its use; or, finally, the complications, and, in some respects, failures of early effort in this line, have joined, with the prejudice that progress always meets, to cast, on the compound principle as a whole, a shadow so dense that even able management pauses reluctant on its brink and the worthy engines of to-day fail, therefore, in the recognition which is their due.

As to the first of these propositions, it is hoped that what is hereinafter shown will prove fully that the compound locomotive has not only attained the economy which has been claimed for it; but that, in some forms at least, it has met fully all of the requirements of the most exacting service in its power, control, and ease of operation.



A COMPOUND FAST PASSENGER LOCOMOTIVE BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, PA.

The second proposition implies an impossibility, with wise and intelligent management, even in times of prosperity; and far more so in the years of financial depression, from whose gloom the United States seems now so happily emerging. With many railroads, as with the majority of other enterprises, the seven kine of Pharaoh's dream, "ill-favoured and lean-fleshed," have eaten up, during this period, not only surplus wealth and many dividends that should have come, but have been so famished still that the utmost care and saving have been necessary in making ends meet.

The economies sought by railroad

management in locomotive design have been, however, chiefly " those obtainable by a reduction of the total train expenses, rather than those of the locomotive itself. As a result, we have larger locomotives, heavier trains, engines that stay out of the shop longer, or make a greater mileage between shoppings—in fact, anything and everything, in design and method of operation, that will give the best net result on the capital

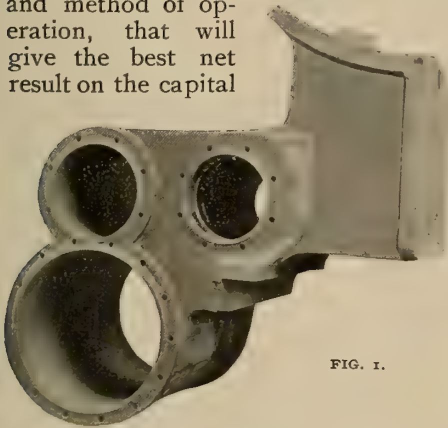


FIG. 1.

BALDWIN COMPOUND LOCOMOTIVE CYLINDERS WITH LOW-PRESSURE CYLINDER BELOW.

invested and which will cut down the expenses per ton-mile."* The single-expansion engine has been improved and enlarged, seemingly, to its utmost limit; with the steady advance in the quality of material, its steam pressure has increased and its power has grown, while its economy has remained stationary or declined, owing to the limited expansion obtainable in the single cylinder necessitating an exhaust at wasteful pressure.

When we note this strenuous effort to save, and remember, as well, that from 60 to 70 per cent. of the entire work of an engine, using 180 to 200 pounds boiler pressure, can be performed by the expanding steam alone, when properly utilised in the compound locomotive, while but from 30 to 40 per cent. of this same work is done by expansion in the simple engine, we realise, not only the vast loss in power and money, but are forced to our final proposition for explanation as to so grave a disregard of steam economy.

The word " compound "—the vague term applied to Woolf's combination of the double-cylinder engine with Watt's condenser—seems, with railroad management, not to have covered, but to have implied, " a multitude of sins." To normal minds, flashes of genius are few. A conception of value presents itself, usually, in its most complicated form; and only when there exists " the infinite capacity for taking pains," can it be reduced to its elements. Through this stage the compound locomotive has progressed; but the merits of the successful engines of this day seem, in great degree, overshadowed by the tradition and prejudice of the past.

Advantages of the Compound Locomotive.

In considering the relative value of the compound locomotive, it should be remembered that it is not a steam engine merely, but that it includes the boiler as well; and that the double-expansion principle has incidental, but im-

FIG. 2. A SET OF BALDWIN CYLINDERS WITH LOW-PRESSURE CYLINDER ABOVE.

portant, effects not only upon the latter, but upon other factors of railroad economy. That the matter may be stated fully, there will be given herein not only the incidental advantages referred to,

* *The American Engineer, Car Builder and Railroad Journal.*

but the well known causes assigned generally for the superior economy of the compound engine *per se*, when compared with the single expansion type.

There may be noted, first, the use, with economy, of high pressures.

The ability of the single-expansion locomotive to utilise increased pressures has not kept pace with the improvement in material which permits them, since its stroke, cut-off, and rate of expansion are limited, and its exhaust-pressure is now wastefully high. Initial pressures, it is true, have risen and have made engines more powerful; but exhaust pressures have grown with them, with, in consequence, greater waste. By compounding the engine, the rate of expansion is largely increased, since steam passes through, and is expanded in, two cylinders instead of one, thus making economically practicable the use of the high initial pressures of the present, with practically no waste, the power remaining in the exhaust being sufficient only for proper draught. Speaking broadly, then, the compound engine utilises, in driving, the wasted power in the exhaust of the single-expansion engine; for equal powers, it must, in consequence, require less steam from the boiler, with a resulting saving in both fuel and water.

There is also reduction in cylinder condensation, owing to the relatively small variation of temperatures in the cylinders of the compound, as compared with that in the single-expansion engine. In the latter, during each stroke, the surface of the cylinder, one cylinder-head, and one side of the piston are cooled down to the temperature of the exhaust steam. The live steam, when entering, must heat these surfaces to its own temperature, condensing, and additional steam flowing in to take its place until this is effected. The range of temperature, and of loss, is then, in both cylinders, that between the temperatures of the live and exhaust steam.

In the compound engine this range is, in each cylinder, much less. In the high-pressure cylinder it extends between the temperatures of the live and receiver steam only; and, in the low pressure cylinder, between the temperatures of the receiver and exhaust steam. Heat expended in warming cylinder walls is obviously lost in power, and, since the range of temperature is less in the compound engine, there is, with it, in this, a further saving.

As to the matter of combustion in the boiler, it is to be noted, to begin with, that the tractive force of a locomotive is the force which, coming from the cylinders, is assumed to act on the circumferences of the driving wheels, tending to turn them on their axes. The resistance met by it is the friction between these wheels and the rails. The amount of this adhesion necessarily limits the tractive force, since, if the latter exceed the former, the wheels will rotate without advancing. The adhesion, in turn, although influenced by speed and weather conditions, is measured mainly by the pressure of the driving wheels upon the rails. Hence, the cylinder dimensions are proportioned to the weight upon the driving wheels.

With two locomotives, then,—one single-expansion and one compound, but both of the same size and type,—the boilers must be practically the same in each, since, other things being equal, the weight of either boiler can be such only as the intended pressure on the driving wheels will allow. Both boilers will have, then, equal heating and grate surfaces, but, as has been shown, the compound engine will require from its boiler less steam, owing to its increased rate of expansion and decreased cylinder condensation. There are possible with it, therefore, a milder draught, lower exhaust-pressure, slower rate of combustion, greater absorption of heat from the products of combustion, and a less temperature and resulting loss, in the waste gases of the smoke-stack. The economy noted previously has been that of the engine alone. It will be observed, however, that, in the slower rate of combustion practicable with the compound locomotive, there is a further and distinct saving within the boiler.

Professor W. F. M. Goss, in an able paper on "The Effect of High Rates of Combustion upon the Efficiency of Locomotive Boilers," has discussed the

results of experiments carried out recently in the locomotive laboratory of Purdue University. He says, in part, as to the locomotive experimented upon and the coal used (Brazil block):—

"It appears that, when coal is burned at the rate of 50 pounds per square foot of grate per hour, 8 pounds of water are evaporated for each pound of coal; while, if the rate of combustion is increased to 180 pounds per square foot of grate, the evaporation falls to about 5 pounds—a loss in water evaporated per pound of coal of nearly 40 per cent. This loss may be due to a failure of the heating surfaces to absorb properly the increased volume of heat passing over them, or to the imperfect combustion of the fuel upon the grate, or it may be due to a combination of these causes. * * * The results show that the most efficient furnace action accompanies the lowest rates of combustion."

In summing up the total saving in fuel and water with the compound locomotive, we find that it arises from three sources, viz., the higher rate of expansion, the reduced cylinder-condensation, and the slower rate of combustion. These considerations affect not only the cost, and dead weight carried, of fuel and water, but, more remotely, other matters to be referred to hereinafter.

As regards repairs and maintenance, the compound engine is subject to much lighter strains at the beginning of, and to less variation in strain during, the stroke than the single expansion engine; hence, the friction on journals and guides will be less and it will run more steadily than the single-expansion engine. If the working parts are of the same dimensions in both, it follows that, with the compound, there will be reserve strength and durability. These are advantages which are inherent with the compound system, when it is properly applied. Now, the initial load, or blow, occurs at the beginning of the stroke—the "dead centre"—when there is no turning effect and it is felt throughout the mechanism in pins, bearings, and bolts. Obviously, any lessening of its force should bring, in some degree, a lessening also in the need of adjustment and repair. Similar reasoning applies to a reduction of the variation in strain during the stroke.

With the boiler of the compound locomotive, the slower combustion and smaller amount of fuel mean less "forcing," a lower fire-box temperature, a reduced range of expansion and contraction of material, and greater durability. There being also less water evaporated, the amount of foreign matter in the boiler will be less, thus decreasing the number of washings required and the time lost while out of service.

Against these advantages in repair and maintenance must be set the care and repair of such additional parts as the compound engine gives the locomotive. These vary in number and character, with different types. It has been fully shown, however, in long service, with some of those to be described, that the cost of repair and maintenance in the compound locomotive is not higher, but equal to, or less than, that of the single-expansion engine, since the added parts are relatively few and simple, the driving mechanism is much the same, and the wear and tear of the boiler are less.

With regard to the tractive power, some compound locomotives exert maximum effort by admitting live steam to the low-pressure cylinder, while others are capable of conversion, simply and quickly, into single-expansion engines, the high-pressure exhaust being opened to the atmosphere and live steam being admitted to the low-pressure cylinder. This gives the engine, in some cases, an increase in power of 25 to 30 per cent. One of the peculiarities of railroad service is that the adhesion varies considerably, while, in the single expansion engine, it is not possible to vary the factor for maximum tractive force. The reserve power of the compound, as noted above, gives this varying factor for critical times.

In general practice, the maximum tractive power should be about 22 per cent. of the adhesive weight, in order to meet all changes in weather and rail conditions without excessive slipping. At times, however, a higher percentage

can be used with advantage; as, for instance, in a sharp curve, up grade, at slow speed, where the outer rail is higher than the inner. The wheel flanges, then, press against the inner rail, thus increasing the frictional resistance of the engine as well as its adhesion to such an extent that the tractive, or cylinder, power can be run up to 30 per cent., or more, of its adhesive weight for temporary use. At such times, the compound locomotive, with its reserve power, will take a train over a grade that would stall a simple engine of equal weight and factor of tractive force.

With the same weights of coal and water carried as in the single expansive engine and with the reduction in the amounts used by the compound locomotive, a corresponding reduction may be made in the number of water-tanks and coal-stations along the line, thus giving greater range in selecting stations where good water may be found and lessening the cost of maintenance and supply. Spark-throwing is an evil in railroading against which, with the strong exhaust of the single-expansion engine, there seems to be no adequate safeguard. Large sums are paid annually as damages by roads on which combustible vegetation and flying sparks combine to produce destructive fires. With the mild exhaust and reduced draught of the compound locomotive, fewer sparks are drawn from its furnace and there is, as well, a greater tendency to retain them in the smoke-box. In some tests, the actual weight credited to "sparks" has been shown, for the compound, to be but about 50 per cent. of that from the single-expansion engine. Absolute immunity from the danger noted would be, perhaps, too strong a claim for the compound locomotive; but it is stated that no such fires, owing to it, have yet been reported. On roads where there is much inflammable matter, the protection thus given would seem to be of grave importance. On all roads, however, spark-throwing is by no means a negligible factor in the economies of combustion. In the paper by Professor Goss, to which reference has been made previously, he gives, as the result of tests with rates of combustion varying between 64 and 241, values of spark-losses, in per cent. of coal fired, ranging between 4.3 and 15.5; and says further:—

"According to popular judgment, the loss of heat by sparks has always appeared small; while the data show, that, under conditions which are now common, it may represent more than 10 per cent. of the fuel value of coal fired."

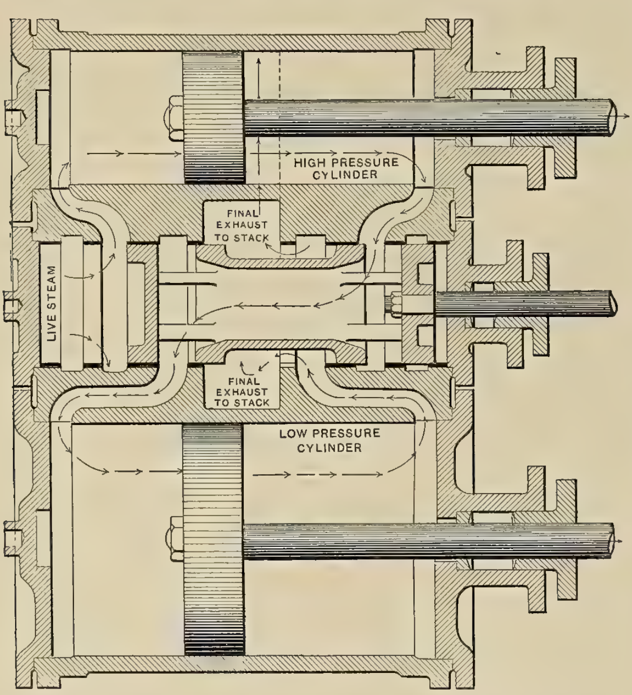
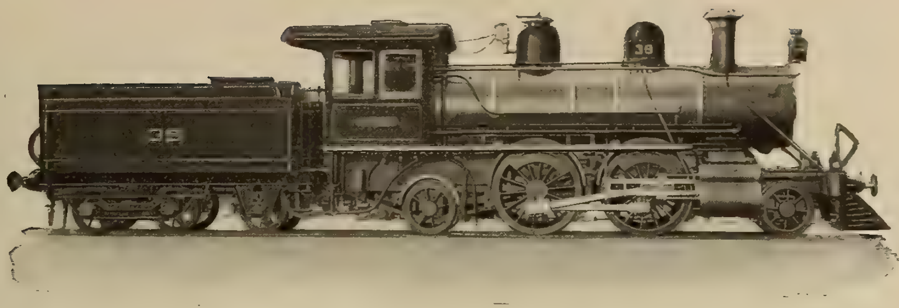


FIG 3. SECTION OF BALDWIN COMPOUND LOCOMOTIVE CYLINDERS AND VALVE CHAMBER.



A NARROW-GAUGE BALDWIN COMPOUND LOCOMOTIVE BUILT FOR THE SAMYO RAILROAD IN JAPAN.

Requirements of the Compound Locomotive.

To be wholly successful, it seems clear that the compound locomotive must not only show the saving in fuel and water due to the compound principle, but that it must have an efficiency, in power and its control, equal in all respects to that of the single-expansion engine, with an absence of complexity and a cost of repairs and maintenance, which, considering other economies, shall not seem excessive. As to the power and its control, it may be said, with regard to all types, in view of the present state of the art, that to avoid jerking and racking, the power developed, either in single-expansion or compound work, should be the same on both sides of the locomotive; that, in starting a train, or in emergencies, the engine should be capable of developing its maximum power; that there should be automatic control, if possible, of the employment of single expansion, to prevent its unnecessary and wasteful use for long periods; that, to prevent rough riding and reduce the effect of the air-jet on the fire when steam is shut off on a down grade there should be an adequate system of air-circulation or relief applied to the cylinders, when the volume of the latter is sufficient to require it; and, finally, that, other things being equal, the more the mechanism for effecting the foregoing combines automatic operation with simplicity the more practicable the system would seem to be.

It is not possible to discuss fully, herein, all types of the American compound locomotive which have been brought forward. As full description as is available, however, but without criticism or comparison, will be given of some leading systems.

The Baldwin (Vauclain) System.

On each side of the Vauclain compound locomotive there are one high-pressure and one low-pressure cylinder, the volume of the latter being thrice that of the former. The axes of the cylinders are horizontal, parallel, in the

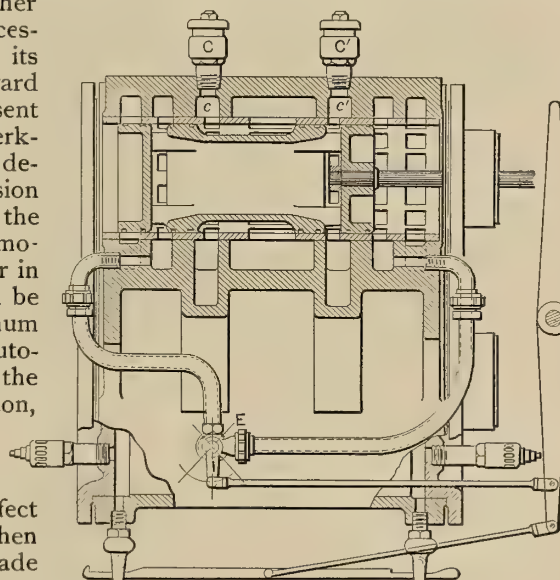
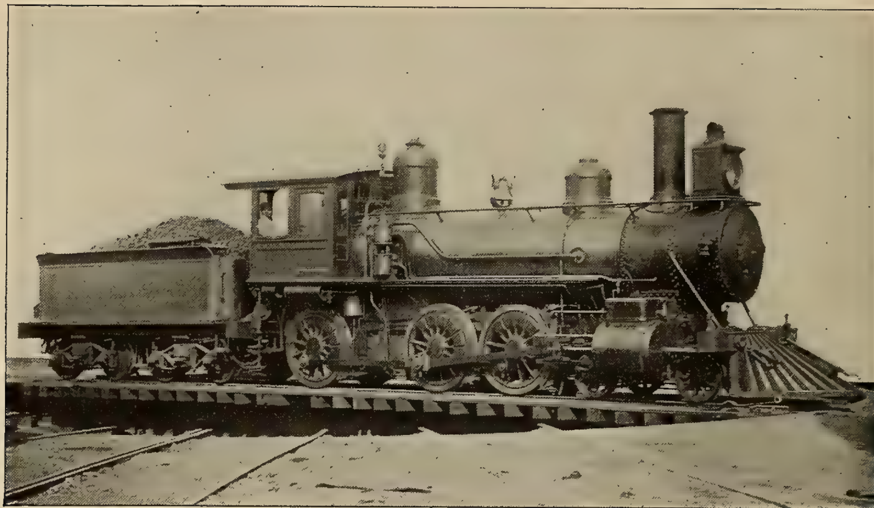


FIG. 4. BALDWIN LOCOMOTIVE VALVE CONNECTIONS.



THE FIRST RICHMOND COMPOUND LOCOMOTIVE, BUILT BY THE RICHMOND LOCOMOTIVE AND MACHINE WORKS. RICHMOND, VA.

same vertical plane, and the one directly above the other. The two piston-rods of each side are fixed in a common crosshead, one above, the other below, the crosshead pin. The cylinders of one side are cast in one piece with the valve-chamber and saddle, the cylinders and chamber being as close together as adequate walls between will permit. The style of framing determines the location of the low-pressure cylinder in the lower position, as in Fig. 1, or in the upper position, as in Fig. 2, as well as the form of the valve-motion.

It will be observed that, in this system, there are one high-pressure and one low-pressure cylinder on each side, or four cylinders in all. The driving mechanism consists, then, of two complete compound engines for each locomotive.

Fig. 3 gives, in sectional view, the Vauclain cylinders and valve-chamber for one side. As shown, the distribution of steam, for both the high-pressure and low-pressure cylinders, is effected by one valve of the piston type—double-ended, hollow, and practically balanced, since steam, for the high-pressure cylinder enters the steam-chest at both ends.

In starting, and in emergencies, as when stalling with a heavy train on a grade, live steam may be admitted to the low-pressure cylinder, thus obtaining additional power. This is effected through the "starting valve" *E* (Fig. 4), which is merely a by-pass, that, when opened, allows steam to pass from the steam to the exhaust side of the high-pressure piston and thence to the steam side of the low-pressure piston.

As to this valve, the builders state that it acts "as a cylinder cock for the high-pressure cylinder and is operated by the same lever that operates the ordinary cylinder cocks, thus making a simple and efficient device and one that need not become disarranged. This valve should be kept shut as much as possible, as its indiscriminate use reduces the economy and makes the locomotive 'logy.'"

In addition to the usual air-valves on the main steam passage of the high-pressure cylinder, other air-valves, *C*, *C* (Fig. 4), are fitted to the low-pressure cylinder, so that there may be no vacuum formed, at any time, in the latter. Water relief-valves of ordinary type are attached to both heads of the low-pressure cylinder. As to the operation of locomotives of the Vauclain system, the builders state:—

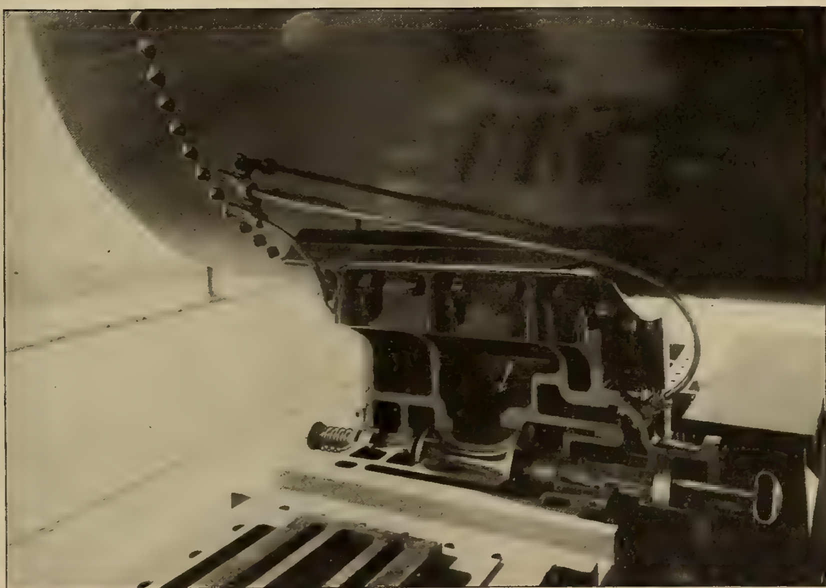
"It is not surprising, in view of their differences of opinion respecting single-

expansion locomotives, that there has been much controversy among engineers and firemen in regard to the operation of compound locomotlves of this system.

"The first thing the engineer must learn is to use the reverse lever for what it is intended, that is, he must not hesitate to move it forward when ascending a grade, if the locomotive shows signs of slowing up. The reverse quadrant is always so made that it is impossible to cut off steam in the high-pressure cylinder at less than half stroke, which avoids the damage that might ensue from excessive compression. It is perfectly practicable to operate the engine at any position of the reverse-lever, between half-stroke and full stroke, without serious injury to the fire. * * *

"In case the locomotive is attached to a passenger train and standing in a crowded station, or in some position where it is undesirable to open the cylinder-cocks, the engineer should move the cylinder-cock lever in position to permit live steam to pass by into the low-pressure cylinder, thus enabling the locomotive to start quickly and uniformly. * * * After a few revolutions have been made, and the cylinders are free from water caused by condensation or priming, the engineer should move the cylinder cock lever into the central position, causing the engine to work compound entirely. * * * The reverse-lever should never be 'hooked up,' thereby shortening the travel of the valve, until after the cylinder cock lever has been placed in the central position. * * *

"The starting device should not be used for any purpose other than the starting of the train. After the train is in motion it should not be used. Cases have been observed where the engineers use it all the time and have the reverse lever 'hooked up' in the top notch (half stroke), in consequence of which the locomotive will slow down to a low speed while burning an excessive amount of coal. Such running must result in general dissatisfaction.



SECTIONAL VIEW OF INTERCEPTING AND OTHER VALVES OF A RICHMOND COMPOUND LOCOMOTIVE.

"The starting device is useful in emergencies, as, for instance, when stalling with a heavy train on a grade; if live steam is admitted to the low-pressure cylinder, sufficient additional

power is obtained to start the train and take it over the grade. This should be resorted to only in emergencies and allowance should be made for the extra repairs caused by frequent cases of this kind.

"On account of the very mild exhaust, the fireman should carry the fire as light as possible. A little practice will enable him to judge how to get along with the least amount of fuel. * * *

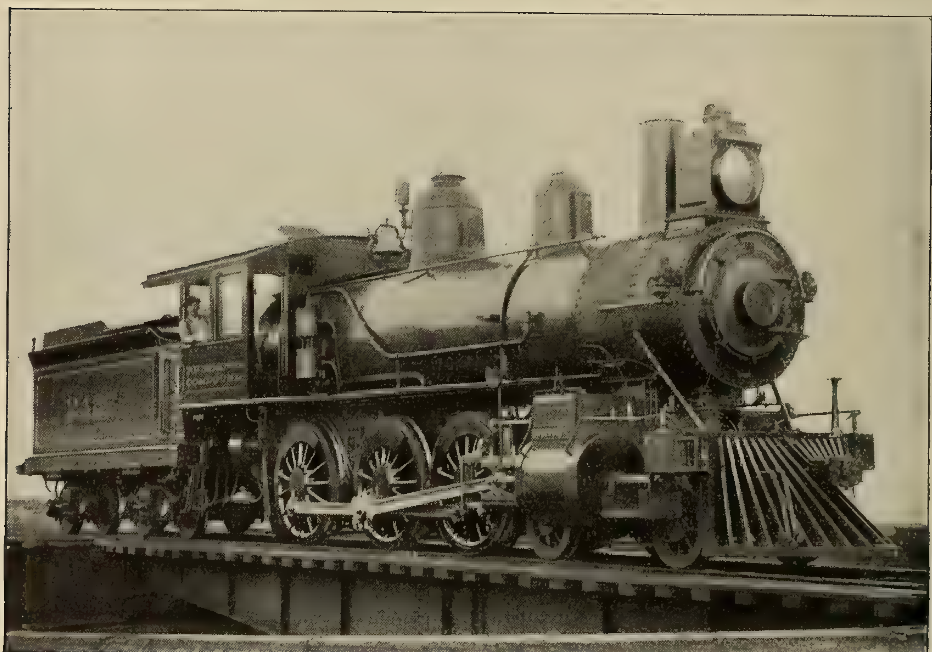
"The water-rate per horse-power varies very little on the compound locomotive when the reverse-lever is moved forward toward full-gear or longer cut-off, but in the single expansion engine it increases rapidly, causing engineers to remark that they cannot 'drop her a notch' on account of 'getting away with the water.' This does not occur with the compound locomotive when the reverse-lever is moved forward toward full gear, and no engineer should open the pass-by valve, admitting live steam to the low-pressure cylinder, until the last notch has been used on the quadrant and the engine is about to stall.

"It is also desirable to move the reverse-lever forward a notch before the locomotive slows down too much, as it is better to preserve the momentum of the train than to slow down and again have the trouble of accelerating. In this way both coal and water are wasted."

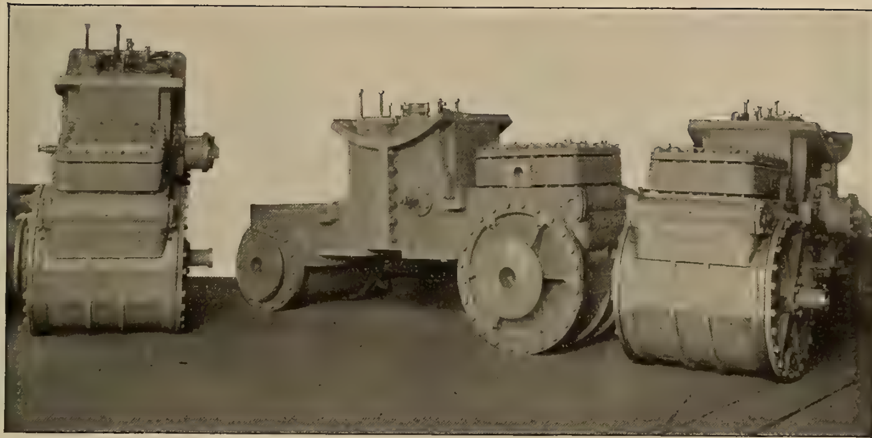
The extracts which follow are from the record of comparative tests of the Vauclain compound and single-expansion locomotives, as given by the builders:—

Date, July, 1891; road, Northern Pacific; test, freight service; locomotives, Mogul; course, 108.7 miles; number of trips, ten; average steam pressure, compound, 157.3 pounds, single expansion, 151.9 pounds; maximum temperature of waste gases in smoke-box of single expansion, 878° F., of compound, 590° F.; maximum vacuum in smoke-box of single expansion, 10 inches, of compound, 6.75 inches; total saving in favour of compound, 22.2 per cent. in fuel and 11.27 per cent. in water evaporated per pound of coal.

Date, August and September, 1891;



A RICHMOND COMPOUND FREIGHT ENGINE.



A SET OF RICHMOND COMPOUND LOCOMOTIVE CYLINDERS.

road, Western New York and Pennsylvania; test, freight service; locomotives, consolidation; course, 70 miles; number of trips, three round; average steam pressures, compound, 166 pounds, single expansion, 147.7; average temperature of waste gases in smoke-box of single expansion, 690° F., of compound 630°; average vacuum in smoke-box of single expansion, 6.4 inches, of compound, 2.9 inches; average increase in favour of compound of 36.2 per cent. in weight of train hauled per pound of coal, and of 17.9 per cent. in water evaporated per pound of coal.

Date, April, 1894; road, Central Railroad of New Jersey; test, passenger service; locomotives, American type; course, 85.1 miles; number of trips, two round, with each locomotive; average boiler-pressure, compound, 164.9 pounds, single-expansion, 157.5 pounds; percentages in favour of compound locomotive:—

In coal consumed during test	19.86 per cent.
In water evaporated from and at 212° per pound of coal on run	18.70 "
In rate of combustion per sq. ft. of grate per hour during run	20.05 "
In tons of train hauled per mile per pound of coal	15.85 "

The comparative performances cited above indicate not only the saving in fuel and water by the use of the compound system, but also the reduction in smoke-box temperature and vacuum.

The performance of one of the engines of this type noted below, shows, further that the compound system is not a bar to high speed in railroad service:—

Date, May 29 to June 11, 1896; course, Camden to Atlantic City, N. J., 55.5 miles; number of runs, 12; average coaches drawn, 4.75, Pullmans, 1.83; average time, 51.42 minutes; average speed, 64.74 miles per hour.

It is stated, that, during the past summer, even better results have been obtained over this course.

The Richmond (Mellin) System.

The Richmond engine is of the cross-compound type, having a high-pressure cylinder on one side, a low-pressure cylinder on the other, an intervening receiver, and an "intercepting valve" in the cylinder-saddle, through which the engine is converted from compound to simple and vice versa. The ratio of low-pressure to high-pressure cylinder is usually about 2.5 to 1.

There are three special valves:—an intercepting valve which controls the connection between the high-pressure exhaust and low-pressure steam supply; a reducing valve which, at proper times, admits live steam to the low-pressure chest and regulates the pressure in the low-pressure cylinder; and an emergency valve, which, when the engine is to be worked in single-expansion, opens connection between the high-pressure exhaust and the atmosphere.

Steam from the dry-pipe passes di-

rectly to the high-pressure steam-chest and also to the cavity surrounding the reducing valve. The exhaust from the high-pressure cylinder goes to the opening surrounding the intercepting valve

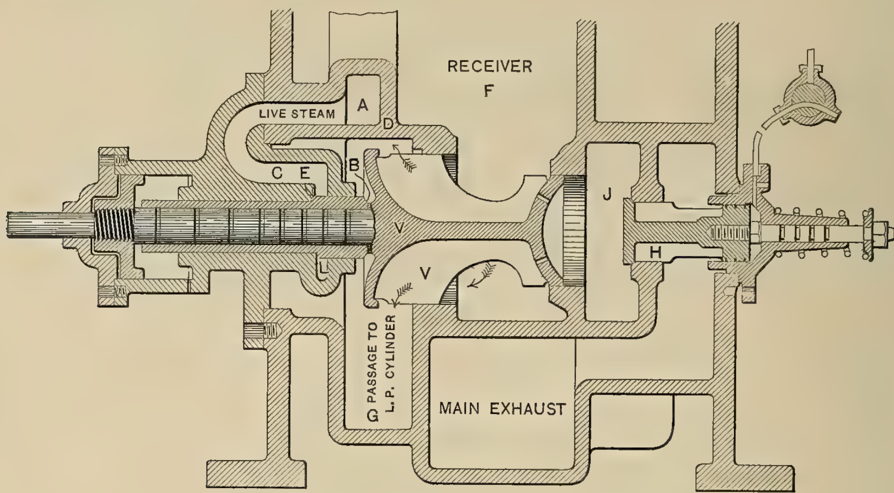


FIG 5. POSITION WHEN WORKING COMPOUND.

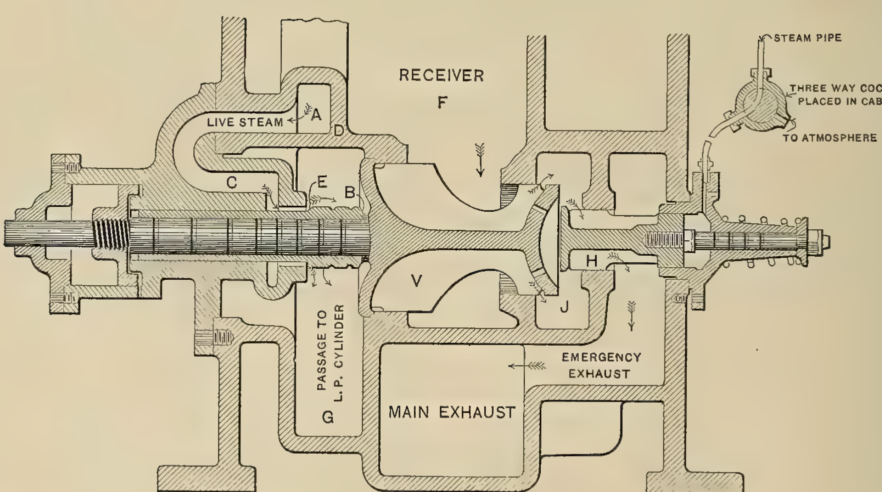


FIG. 6. POSITION WHEN WORKING SIMPLE.

RICHMOND COMPOUND LOCOMOTIVE VALVE SECTIONS.

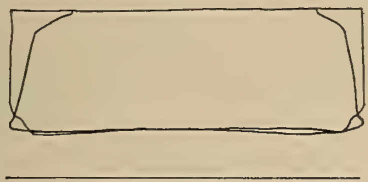
and can flow thence, either to the low-pressure steam-chest or directly to the stack, as the position of the valve determines. The exhaust from the low-pressure cylinder passes to the stack at all times. The valves are placed in the low-pressure cylinder saddle, and the high-pressure exhaust reaches them through a receiver in the smoke-box.

In the photographic view of a portion of a locomotive reproduced herein on page 39 the valves and contiguous parts can be clearly seen, the exterior of the saddle having been cut away. Figs. 5 and 6 show sectional views through the

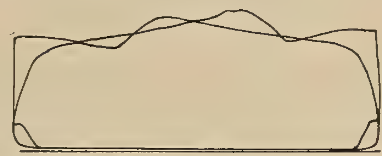
low-pressure cylinder saddle, with the relative positions of the valves at different times.

The operation of the various valves is described, as follows:—

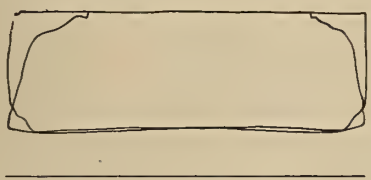
"The high-pressure cylinder exhausts into a receiver, which is placed inside the smoke box and opens into the chamber *F*. The intercepting valve, as shown at *V*, has a piston on its outer end, which acts as an air dashpot, preventing any slamming of the valve. Around the stem of this valve is a sleeve *L*, which has an axial movement on the stem, and acts as an admission and reducing valve to the low-pressure steam chest when starting and when working simple. Valve *H* is a plain, bevel-seated, winged valve, and is called the emergency valve, as by its use the engineer can, at will, operate as a simple engine.



HIGH-PRESSURE.
M. E. P., 112. CYLINDER, 20 IN.
MILES PER HOUR, 11.
PER CENT OF TOTAL WORK, 48.9.

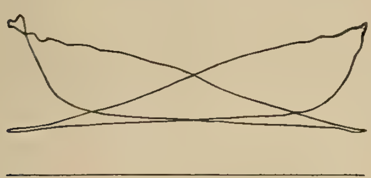


LOW-PRESSURE.
M. E. P., 46. CYLINDER, 32 IN.
PER CENT. OF TOTAL WORK, 51.1.

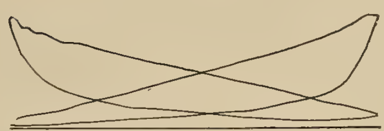


M. E. P., 110. MILES PER HOUR, 16.
PER CENT. OF TOTAL WORK, 51.1.

M. E. P., 41.
PER CENT. OF TOTAL WORK, 48.9.



M. E. P., 36. MILES PER HOUR, 38.
PER CENT. OF TOTAL WORK, 48.4.



M. E. P., 15.
PER CENT. OF TOTAL WORK, 51.6.

INDICATOR DIAGRAMS FROM A RICHMOND COMPOUND LOCOMOTIVE AT DIFFERENT SPEEDS AND UNDER DIFFERENT LOADS.

"When starting, steam from the boiler goes to the high-pressure cylinder in the ordinary way, and also to the port *C* through a three-inch steam pipe connected to the dry pipe. When the throttle is opened, no matter in what position the valves stand, there is no pressure in the receiver *F*, and the pressure on the shoulder *E* of the sleeve *L* moves the sleeve and valve *V* to the right, closing the receiver and letting steam past the shoulder *E* into the low pressure steam chest *G*.

"Now, since the area of the end *B* of the sleeve *L* is, say, twice that of the shoulder *E*, half of the boiler pressure will move the sleeve *L* to the left, cutting off steam through port *C*, and thus equalising the work in both cylinders, since the reduced pressure is thus maintained in the low-pressure steam chest by the reciprocating action of the sleeve.

After, say, one and one-half revolutions, the pressure accumulates in the receiver *F*, due to the exhaust from the high pressure cylinder, and acting against the large face of valve *V*, moves this valve to the left, carrying the sleeve with it, thus opening a straight connection between the high-pressure exhaust and the low-pressure steam chest, and ceiver through holes in the rear end of valve *V*, and then the valve, being unbalanced, moves with the sleeve *L* instantly to the right, assisted by steam pressure on the shoulder *E* of the sleeve. The high-pressure cylinder has now a separate exhaust around the end of valve *V*, through valve *H*, into the main exhaust, since the intercepting

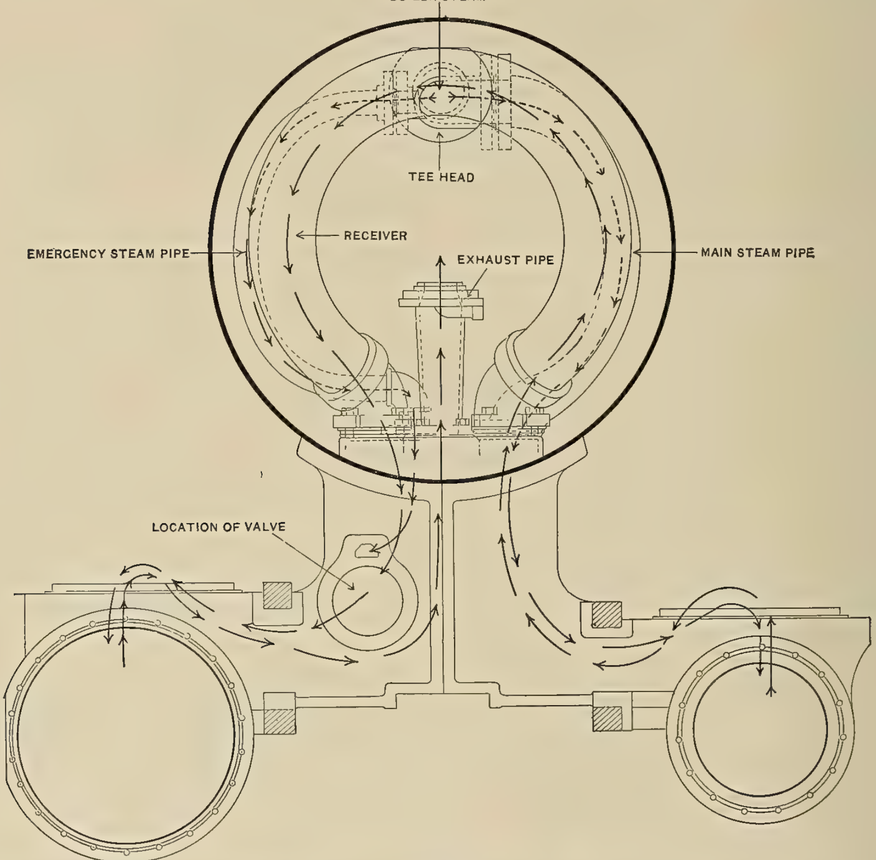


DIAGRAM OF STEAM CONNECTIONS AND STEAM CURRENTS IN THE RICHMOND SYSTEM, WORKING COMPOUND.

at the same time permanently cutting off live steam from port *C*.

"In starting on grades, or when exerting maximum power, the engineer can move the three-way cock in the cab, letting boiler steam behind the piston on the emergency valve *H*, and holding it open against its spring. This exhausts the small cavity *J*, in which the pressure is equalised with the re- valve remains closed, due to no accumulated pressure in the receiver *F*. The low-pressure steam chest then gets reduced pressure steam direct from the boiler through port *C*, and reducing valve *L*.

"Except when working simple, the valves act entirely automatically. The lubricator to the low-pressure cylinder enters port *A*, and thus ensures con-

stant lubrication to the intercepting and reducing valve.

"Owing to the small area of port *C*, and the contracted exhaust through valve *H*, the engine develops less power as a simple engine than as a compound, at a speed of over, say, eight or ten miles an hour, and thus the runner is compelled to work compound. Should either side break down, the emergency valve can be opened and the engine brought in on one side like an ordinary simple engine."

The equal division of the power between the two cylinders, at varying speeds and loads of the locomotive, is effected by giving the low-pressure valve amounts of lead and lap differing from those of the high-pressure valve. Thus, each cylinder has a point of cut-off differing from that of the other, for the same position of the links, the latter being of the usual type. Indicator cards, showing the close approximation to equalisation thus obtained, are reproduced on page 43, through the courtesy of the builders.

The large low-pressure cylinders of the compound locomotive magnify, to an extent of importance, an evil which, with the smaller cylinders of the corresponding single-expansion type, is negligible. When steam is shut off, in running down-grade, the pistons act as air-compressors, producing thumping, rough riding, cooling of the cylinders, and a strong jet in the stack, at a time when no steam and practically no draught are required, with a consequent waste, in excessive blowing from the safety valve.

This action is prevented, in engines of the Richmond system, by certain over-pass valves, one for each end of the low-pressure cylinder, placed together, within a chamber in the cylinder-casting, at the side of the steam ports, as shown in section (Fig. 8). They are wholly automatic in action, opening or closing the ports of two air-passages connecting the steam ports. The valves consist essentially of two pistons, bevelled on their inner faces for seating, when covering the air-ports. The two ports *AA* unite the space at the outer ends of the pistons with the valve-chest. Between the valves there is a small vent *B*, leading to the atmosphere.

When running with the throttle open, steam entering at *AA* moves the valves inward and closes the air-ports, the working conditions being, then, the same as if the entire appliance were absent. As soon as the throttle is closed, with the engine still running on down-grade, the vacuum formed in the valve-chest—assisted, if desired, by a central, intervening spring, as shown—draws the valve outward, thus opening the air-ports and giving communication from one steam port to the other, with a circulation of air to and fro in the cylinder and ports, as the piston reciprocates.

From the description set forth, the engines of this system would seem to be

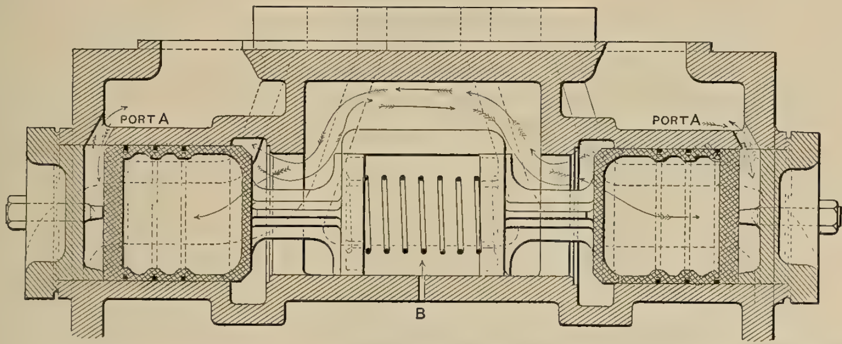


FIG. 8. SECTION OF OVER-PASS VALVES IN THE RICHMOND LOCOMOTIVE. RUNNING WITH THROTTLE CLOSED.

COMPOUND FREIGHT ENGINE, BUILT BY THE SCHENECTADY LOCOMOTIVE WORKS, SCHENECTADY, N.Y.

wholly automatic in their convertibility, excepting when, in emergency, the cock in the cab is opened for continuous single-expansion, or closed to return to the compound principle. In ordinary starting, the maximum power is, at first, developed, automatically and without using the emergency-valve, since there is, then, no pressure in the receiver, and, consequently, no back-pressure in the high-pressure cylinder, while the reducing valve *L* opens at once to admit live steam to the low-pressure cylinder. Very quickly thereafter, the engine is converted automatically to the compound system through the accumulation of steam in the receiver. In conformity with the ruling principle of the system, the over-pass mechanism is also automatic. As to the design and operation of this locomotive, the builders state:—

"The intercepting valve proper is automatic, responds positively to variations of pressure, and allows the engine to start, without jerking, regardless of reverse-lever or crank positions. The engine is also convertible into the single-expansion type whenever the engineer may deem this necessary for extraordinary pulling on hills and curves, where flange friction aids the adhesion; and an increase of from 25 to 30 per cent. in tractive power is thus

obtained at slow speeds. * * * It (Richmond) is the only system that is provided with over-pass valves to avoid air-compression in the cylinders and thumping, and to reduce the air-jet, when steam is shut off in running down-grade. * * * The engineer has nothing more to attend to on the compound of this type than on a single engine, except, in an emergency, when he will be very glad to turn the handle of a cock, that he may get over a hill, when he is about to 'stall.'"

The extracts in Table 1 from a report of the performance of a Richmond compound locomotive, as compared with that of simple engines of the same class, the writer is enabled to present through the courtesy of Mr. W. S. Morris, Superintendent of Motive Power of the Chesapeake and Ohio Railroad, an official who has had extended experience with the compound locomotive and whose early and able advocacy of the double-expansion system would seem to have been based on most careful investigation.

The engine referred to is Richmond Compound No. 140, illustrated on page 38, whose performance, for four years, is compared with that of the single-expansion locomotives, during the same period, on the same road, and doing similar work. All, according to Mr. Morris, were "of the same class, carrying the same steam pressures, and identical in every respect, except that one is a compound and the others are ten simple engines."

There are, on record, few, if any, reports of comparative service so comprehensive, or covering so long a period, as that from which extracts are cited above. The mileage, per year (freight service), was, of the simple engines, 34,916, of the compound, 41,297, giving the latter a total mileage 18.3 per cent. greater than the single-expansion engine; and, in doing this larger share, it ran 19.2 per cent. more miles per ton of coal and 30.9 per cent. more per pint of oil.

In the cost per mile run, there was, with the compound, a saving of 21.3 per cent. in fuel, the full amount claimed for the system. Its cost for repairs was very nearly equal to that of the single-expansion engines, the excess being but nine-tenths of one per cent.; while the fact that its charge per mile for oil, waste, wages, cleaning, etc., was considerably less, would seem to justify the claim that its care and operation are neither more difficult nor more expensive than those of the single-expansion engine.

The performance of engines of this

Table I.—Performance of Richmond Compound No. 140.

Chesapeake and Ohio R. R., James River Division. Performances of Locomotives During the Years 1893-4-5-6.	Average per Engine of ten, Single-Expansion.	Richmond Compound No. 140.	Compound's Percentages. More.	Less.
Total mileage, four years	139,666	165,187	18.3	
Miles run to one pint lubricating oil	19.36	25.35	30.9	
one ton of coal	14.64	18.45	19.2	
Cost per mile run in cents:—				
For repairs	3.04	3.07	0.9	
For oil and waste	0.25	0.21		8.0
For fuel	4.69	3.69		21.3
For engineer and fireman	6.06	5.88		3.0
For cleaning and washing	0.20	0.19		5.0

Table II.—Comparative Coal Consumptions.

Big Four Railway. Two Compounds Tested with 12 Exactly Similar Simple Engines.	Pounds of Coal per Car-Mile. Average of 12 Simple Engines.	Richmond Compound No. 472.	Richmond Compound No. 429.	Amount of Coal Saved by Compounds.
During 9 months, 1894	4.80	3.70	----	23 per cent.
" 1 " 1895	3.96	2.89	2.99	26 "
" 8 " 1896	4.64	3.31	3.68	25 "

system is given further in the summaries in Table II, furnished by the builders, from the reports of railroad officials. has been in continuous service since September, 1894, on various railroads. Although designed for a fast freight en-

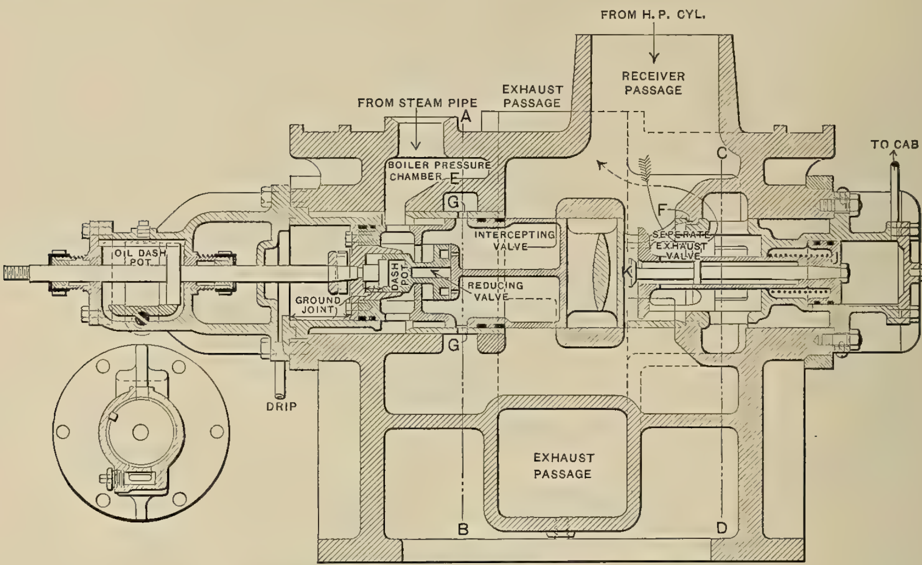


FIG. 9. POSITION OF VALVES WHEN ENGINE IS RUNNING SIMPLE.

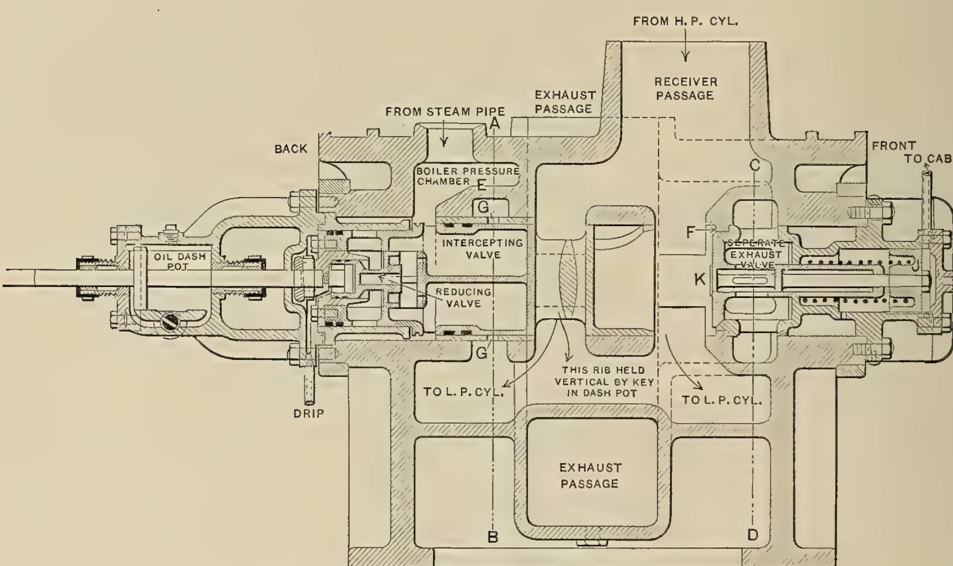


FIG 10. POSITION OF VALVE WHEN ENGINE IS RUNNING COMPOUND.

THE SCHENECTADY COMPOUND LOCOMOTIVE.

The Richmond "Tramp" compound, illustrated herein, built to show the qualities of this compound system, gine, it has been run, it is stated, in every service from switching and slow, heavy pulling to the fastest passenger express

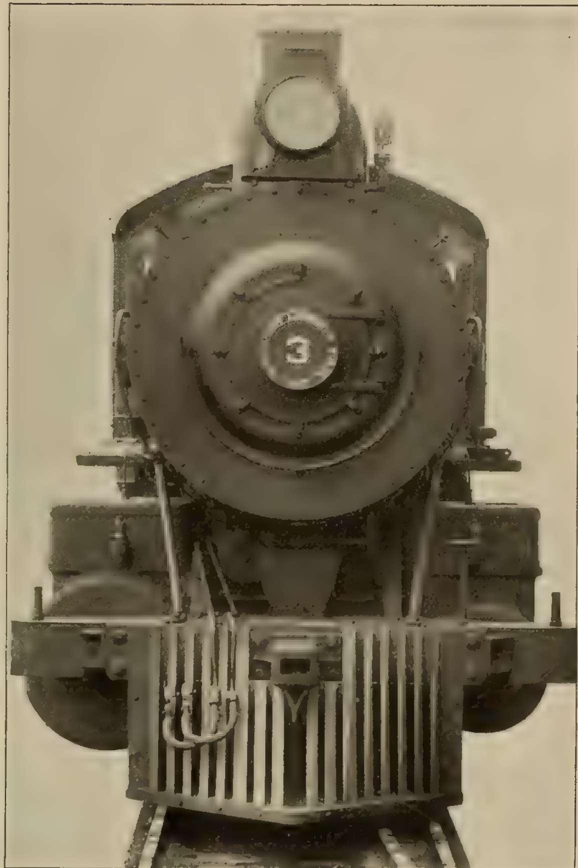
runs. Despite the difficulties of meeting the varying conditions of many roads and of using many different qualities of coal, and the fact that its crew is said to have been changed with every transfer to a new road, the following is given by the builders as a summation from official reports, with regard to its economy of fuel:—

Percentage of coal saved in long service tests:—On Chesapeake and Ohio, 33.2; Pennsylvania, 29.8; Chicago, Rock Island and Pacific, 17.3; Chicago and Northwestern, 17.5; Chicago, Milwaukee and St. Paul, 16.6; Chicago and Grand Trunk, 34.9; Louisville and Nashville, 33.3. Average, 26.1.

The Schenectady (Pitkin) System.

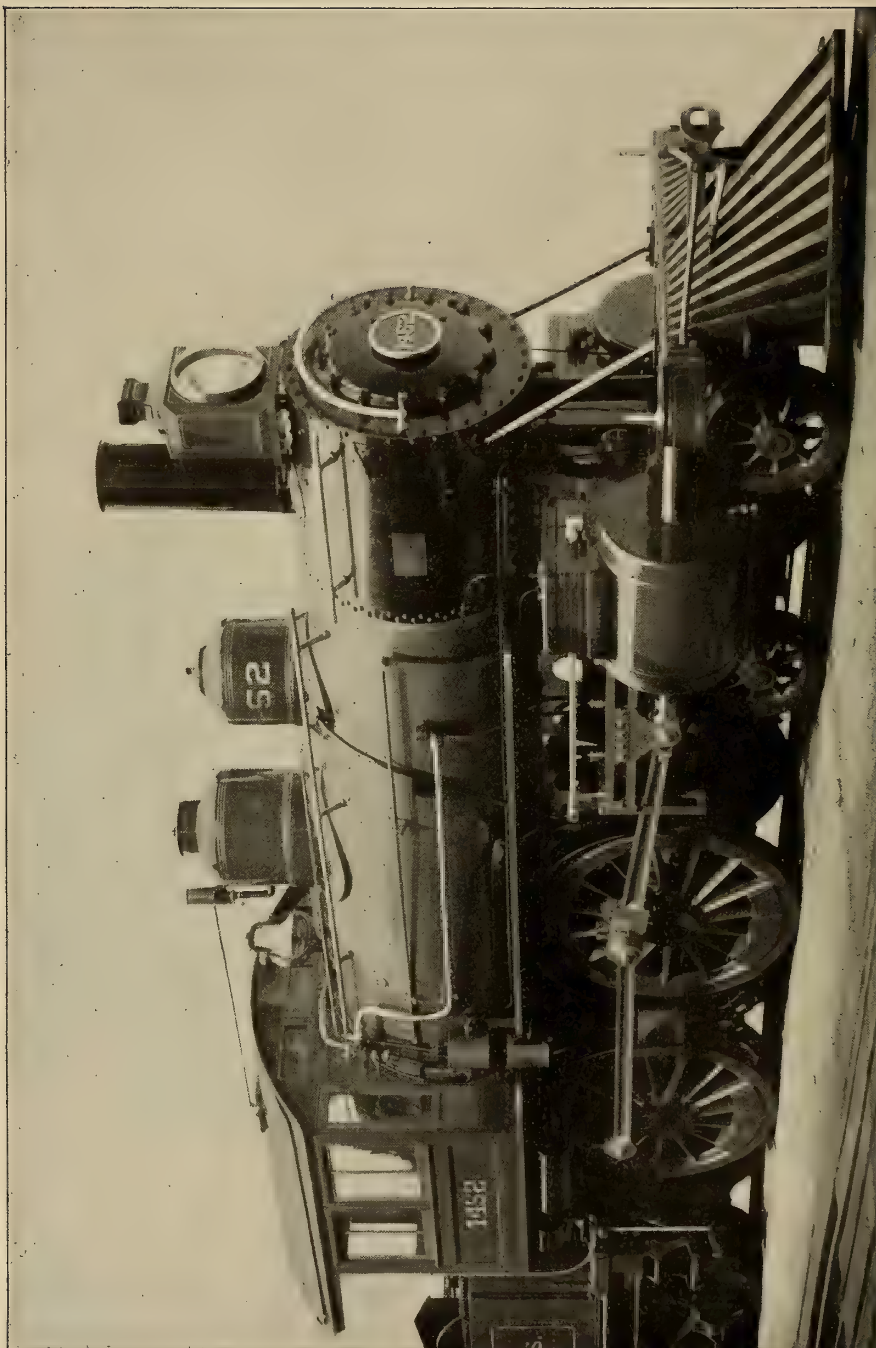
The Schenectady compound locomotive is also of the cross-compound type, having, between the one high-pressure and the one low-pressure cylinder, intercepting, reducing, and separate exhaust valves located in the cylinder-saddle. New designs of this mechanism—those shown herein—have been introduced recently.

Figs. 9 and 10 give longitudinal sections through the valves referred to, as fitted in the 12-wheeled compound locomotive, built for the Northern Pacific Railroad and illustrated herein. The separate exhaust valve, when open, allows the steam to exhaust directly from the high-pressure cylinder to the atmosphere; it is operated by the engineer, through a three-way cock in the cab. The intercepting valve opens and closes the passage between the cylinders, and, through the reducing valve carried by it, admits live steam, at reduced pressure, to the low-pressure cylinder, when the engine is working in single expansion. Both of the latter valves are moved automatically by the steam pressures acting on the difference of areas of their ends and their stroke is cushioned by dash-pots. The operation of the mechanism is described as follows:—



A FRONT VIEW OF THE SCHENECTADY LOCOMOTIVE.

"First, to start simple. Under ordinary conditions, this is not necessary, but, if the maximum tractive power of the engine is to start a heavy train, the engineer pulls the handle of the three-way cock, so as to admit pressure on the piston *J*. This will force piston *J* into the position shown in Fig. 9, which opens the separate exhaust valve and holds it open. As soon as the throttle



COMPOUND LOCOMOTIVE BUILT BY THE PITTSBURGH LOCOMOTIVE WORKS, PITTSBURGH, PA.

is opened, steam at boiler-pressure enters the chamber E and forces the intercepting valve against the seat F, as shown in Fig. 9.

"Steam enters the high-pressure cylinder and is exhausted through the receiver-pipe and separate exhaust valve to the atmosphere, as shown in Fig. 9. Steam also enters the low-pressure cylinder from chamber E, through the reducing valve and ports G, and is exhausted in the usual way. The steam is prevented from reaching the low-pressure cylinder at boiler-pressure by going through the reducing valve. As will be seen from Fig 9, the valve is partly balanced by the cylinder open to the atmosphere, and the boiler-pressure, acting on the unbalanced area, throws the valve to the right. When the pressure on the right of the valve becomes high enough, it will throw the valve to the left,—because it acts on the whole area of the valve,—and, in so doing, throttles the steam to the proper pressure for the low-pressure cylinder.

"Having started the train in this way, when the engineer wishes to change the engine from running simple to running compound, he pushes the handle of the three-way cock to its first position, which relieves the pressure on the right of the piston J, and the spring throws that piston to the right, as shown in Fig. 10, closing the separate exhaust valve. As soon as this valve is closed, the pressure in the receiver rises and presses the intercepting valve to the left, against the pressure in chamber E, which acts only as an unbalanced area of the valve. The receiver-pressure holds the intercepting valve to the left, as shown in Fig. 10, closing the ports G, and opening a free passage from the high-pressure cylinder to the low-pressure cylinder, and the engine works compound.

"It will be noticed that, while working compound, which is the usual way of working the engine, the intercepting and reducing valves are both held against ground joint seats, which prevent the leakage of steam that may have leaked past the packing rings.

"Now, with the engine running compound, if the engineer wishes to run the engine simple, because of a heavy grade, he pulls the handle of the three-way cock the same as for starting simple. This will open first the by-pass valve K and then the separate exhaust valve, the by-pass valve relieving the pressure more gradually than if the large valve was opened at once. As soon as the separate exhaust valve is open, the pressure in the receiver drops and the intercepting valve is forced against the seat F by the pressure in chamber E, and the engine runs simple, as before. When the grade is passed, the engineer pushes the handle of the three-way cock over and the engine begins to work compound.

"To start the engine compound, the separate exhaust valve is left closed, as in Fig. 10, and, when the throttle is opened, the intercepting valve will be forced against the seat F, by the pressure in chamber E, as shown in Fig. 8. The low-pressure cylinder will then take steam through the ports G and the high-pressure cylinder will exhaust into the receiver for a few strokes of the engine. This will raise the pressure in the receiver and force the intercepting valve into the position shown in Fig. 9, closing the ports G, and the engine will run compound."

Reports of comparative tests of locomotives fitted with the earlier Schenectady mechanism showed very good results; those of its performance, as recently modified, are not available at this writing.

The Pittsburgh (Colvin) System.

The cross-compound type is seen also in this engine. In the receiver, there is located a change-valve, the reciprocation of which effects the conversion from simple to compound working, and vice versa. The stem of this change, or intercepting valve, is operated, through intermediate connections, by the piston of a small steam cylinder, the latter being fixed to the side of the engine near the cab. To this cylinder, steam is admitted by a valve actuated, primarily, by a pin on the reverse-lever, when the

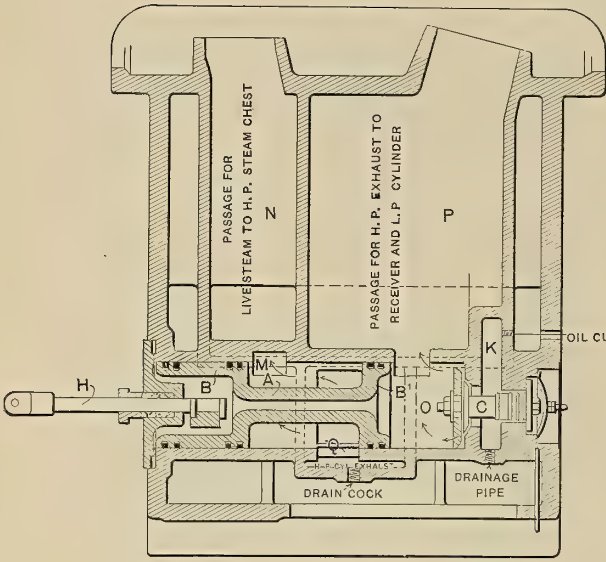


FIG. 11. WORKING SIMPLE.
THE PITTSBURGH SYSTEM.

the port *Q* and the passage *P*, through the port *B'*. The high-pressure exhaust then becomes the supply steam for the low-pressure cylinder and the engine works as a compound. *C* is made a reducing valve in order to prevent excessive pressure in the low-pressure cylinder when live steam is admitted from the duct *K*."

The Pittsburgh, Richmond, Gölsdorf and Von Borries are the four systems of compounding, with which, in 1896, the managers of the Pennsylvania Railroad began a most thorough series of tests in actual service, comparisons being made from the performances of four Mogul freight engines, similar in every respect, excepting that the system of compounding differed in each.

latter has its extreme throw in either direction.

Figs. 11 and 12 give views, in section, of the intercepting and reducing valves, which are placed between the cylinders. *N* is the passage for live steam to the high-pressure cylinder; *Q*, the high-pressure exhaust; *M*, a passage leading to the atmosphere; *P*, a chamber connecting high-pressure exhaust with receiver and low-pressure cylinder; *K*, is a duct through which live steam may enter beyond the reducing valve *C*.

"When the intercepting-valve *A* is moved to the left, as in Fig. 10, the passages *Q* and *M* are connected, the high-pressure exhaust escapes to the atmosphere, live steam from *K* passes the reducing valve *C*, and, through the passage *P*, enters the low-pressure cylinder. The engine works, then, in single-expansion. When the valve *A* moves to the right, as in Fig. 12, it closes the reducing valve *C*, thus shutting off the supply of live steam to the low-pressure cylinder. It masks also the port *M* leading to the atmosphere and opens communication between

The Brooks Tandem System.

There is illustrated herein the tandem, four-cylinder compound locomotive brought out by the Brooks Locomotive Works, of Dunkirk, N. Y., U. S. A. The high-pressure cylinder is placed ahead of the low-pressure.

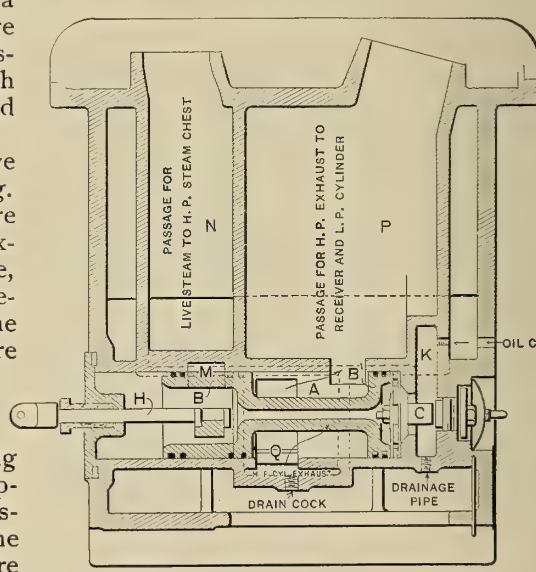


FIG. 12. WORKING COMPOUND.

The exhaust steam from the front end of the high-pressure cylinder reaches the receiver through the centre of the high-pressure valve, the latter being of the piston type and hollow, its interior being lined with wrought iron pipe and having asbestos filling in the space between the pipe and valve. The low-pressure cylinder is equipped with a slide-valve of ordinary type. These valves have, relatively to each other, an opposite motion, *i.e.*, when the high-pressure valve advances, the low-pressure retreats, and *vice versa.*

In starting, maximum power is obtained by admitting live steam to the low-pressure cylinder through a reducing valve which is spring-pressed, to close under normal conditions. When, however, the valve-motion is thrown into full forward or backward gear, projections on the rod connected to the reverse-shaft arm, force the spring downward and the valve open, thus admitting steam, as stated.

This company builds also an engine fitted with intercepting and reducing valves, etc., on the Player system, a description of which is not, at present, available.

While space and other considerations necessarily make this review somewhat incomplete, it would appear that even a partial investigation reveals strong testimony—which, indeed, may fairly be called evidence—as to the marked value of the compound locomotive. All records quoted show its economy and those which treat further of its repairs and operation, indicate that these, with some types, at least, are, respectively, neither more costly nor more difficult than those of the single-expansion engine.

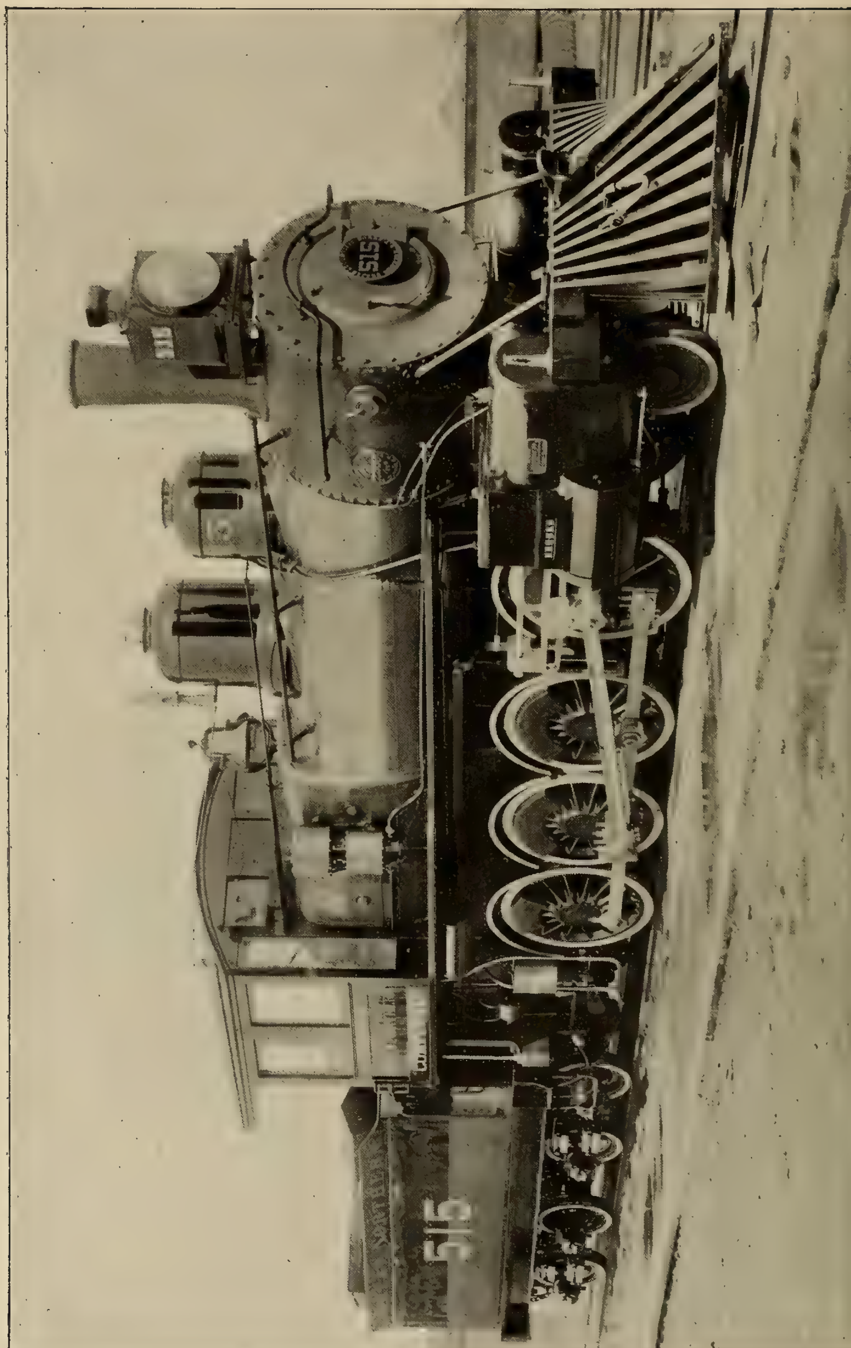
It seems remarkable then, that, with the advance of multiple expansion in all other lines of industry, the compound principle should make such slow progress in railroad service. For fully a decade, despite steady improvement in its design and construction, the compound locomotive has been awaiting recognition. History but repeats itself in this. Mr. Charles E. Hyde, referring to the long travail of the marine compound engine, said recently, in the pages of this magazine:—

"We have an echo of the battle in the statement once made by Charles Randolph, the late partner of Mr. Elder, that the latter 'on several occasions proposed to give up the making of the combined (*i.e.*, compound) engine and go back to the older, but more wasteful form of engine, rather than continue to combat the difficulties and uphill work of bringing it into general practice.' Any engineer of the present day, who has taken active part in the introduction of triple and quadruple expansion, knows something of the depth of discouragement there indicated."

Able advocates, though in the minority of railroad management, the compound locomotive has had from its early days. One of these, a prominent official who has had wide experience with engines of this type, answered a question of the writer as to their performance, with the assurance:—"If we were to order 500 engines tomorrow, we would have them all compounds." The system is not stationary; it is advancing, if but slowly. Many roads, whose management is of high efficiency, have made, or are making, careful tests to determine its economy and general adaptability for all services.

The problem of combining so great an increase in economy with simplicity and durability of construction, a normal rate of maintenance, and ease of manipulation, has been tedious and difficult of solution. To the ill effects of early experiment, and, in some respects, of early error, are owing, in some degree, the strong prejudice against the system which exists in the minds of many able railroad men.

Cumbrous compound locomotives were built, which needed mercy rather than justice, which were fonder of the shop than of the rail. As to this, however, it should be remembered that expansive power—as that of steam —is a property of gases and not a machine; that a principle is one thing, its application, another; that to ascribe, without investigation, to one compound locomotive the faults or vir-



TANDEM COMPOUND LOCOMOTIVE BUILT BY THE BROOKS LOCOMOTIVE WORKS, DUNKIRK, N. Y.

tues of another, is a method of criticism which would have its parallel, perhaps, in assuming that all fuels are,—without regard to their composition or physical characteristics,—equally good or equally bad.

It has been said that the compound has less power than the single-expansion locomotive. This is partly the fault of early designers. A railroad engineer instinctively judges his engine by the size of the cylinders, and the diameter of the high-pressure cylinder is, therefore, misleading. Locomotives have been built on the same specifications and with the same average power as the single-expansion engine; but these proved weak on roads with long and steep grades where their reserve power was called on too often, with a marked reduction in economy. This taught builders a lesson and the power of the locomotive, as a compound, is now made equal to the maximum of the single-expansion engine.

Again, comparative tests, while conducted with all desire for fairness, have been frequently too brief to give trustworthy data. Mr. C. H. Hudson, the general manager of a Southern road, has said, as to this:—

"All conditions should be alike, save the compounding, and then the engines should be manned alike and have the same character of fuel, substantially the same loads, weather, etc. Further than that, the trial should be of sufficient length to carry it down to every-day work, and should cover the changing of engineers and firemen, as well as all the vicissitudes of weather and work."

But more than all else, perhaps, the foe of the new system has been that prejudice which meets innovation, wherever men labour, on land or sea. We cannot do better than to quote Mr. Hudson's experience in this:—

"I regret to state it, yet it is true, that there was, at the start, a universal prejudice against the compound among the engineers and firemen. They were pronounced failures before they were set up, and, long after they had shown their good qualities, the unfavourable criticism continued. They 'would not start the train'; but they did it. They 'could not run up the long hills'; but somehow they did it quite as easily as the other engines. They 'could not pull within two or three cars of the other engines'; but a year's work shows they averaged larger trains, and, in repeated cases, they have pulled as heavy trains as any engines on the road. But, when they saw the compound passenger engine run the round trip with a tender of coal, and run easily a hundred miles with one tank of water, they had to admit that there was some good in the new departure."

In the misconception and opposition which have been noted, there would seem, at this time, to lie the chief obstacles to the adoption of the compound system on the railroads of the United States. While all types may not be equally successful, comparative tests seem to establish so fully the economy and the general efficiency of the system in some forms as to make the question of the extended use of the latter appear to be one of early settlement.

Indeed, the great and continuing loss which has been noted as coming from the use of single-expansion engines, will, of itself, impel action in the matter, since that loss falls not only on railroads and their management, but on stockholders as well. A technical journal has said:—

"The fuel-bill is one of the heaviest items in railroad expenditure; and a saving of 15 per cent. would enable some railroad companies to pay dividends which have been strangers to that form of pleasure for years."

That the opinions of railroad managers still differ widely on the subject is shown by a phrase in the opening address of the president of a recent railroad convention:—"The compound locomotive is still in the balance." With that official, many—doubtless the majority—of able engineers will differ in his dictum. Some types may be trembling "in the balance"; but the logic of the success of multiple expansion elsewhere, is inevitable; and the possibility that the system, as properly developed, if weighed fully, may

be found wanting, will not be readily admitted.

In proof of this—if proof be needed—the writer ventures to cite the opinion of an engineer, as hard-headed and experienced as he is distinguished in his profession—Commodore Melville, the Engineer-in-chief of the United States navy. He has said:—

"No competent engineer disputes the economy of the compound system, although some railroad administrators may, simply because they do not understand. As to the locomotive engineer—the way to get around his prejudices, when they exist, is to force him to run his engine as a compound, or to discharge him and hire men who will obey orders and make a success of so simple a machine as is the compound locomotive."

John Stuart Mill has said that "all reforms have to pass through three stages, viz., ridicule, argument, and adoption." Through the first of these the compound locomotive has fought its slow way; it is now well into the second; that it may reach soon the happy haven of adoption, must be the wish, not only of the engineer, but of every friend of that noble science which has bound a continent with bands of steel, which has made possible the utmost development of national resources, and with which, as pioneers, the names of Stephenson, in England, and of Oliver Evans and John Stevens, in the United States, are so imperishably connected.

In describing the various types of the American compound locomotive which are herein shown, there have been given, in each case, the details of the system with its performance, as fully as these were available to the writer. Acknowledgment is made of information furnished courteously by the makers of these types and by the officials of the motive power departments of various railroads. It is desired to express especial obligation for full data to the Baldwin Locomotive Works, of Philadelphia, Pa., and the Richmond Locomotive and Machine Works of Richmond, Va., the builders, respectively, of the Vauclain compound, and Richmond compound, locomotives.

SYSTEMATIC BOILER CONSTRUCTION.

By W. D. Wansbrough.

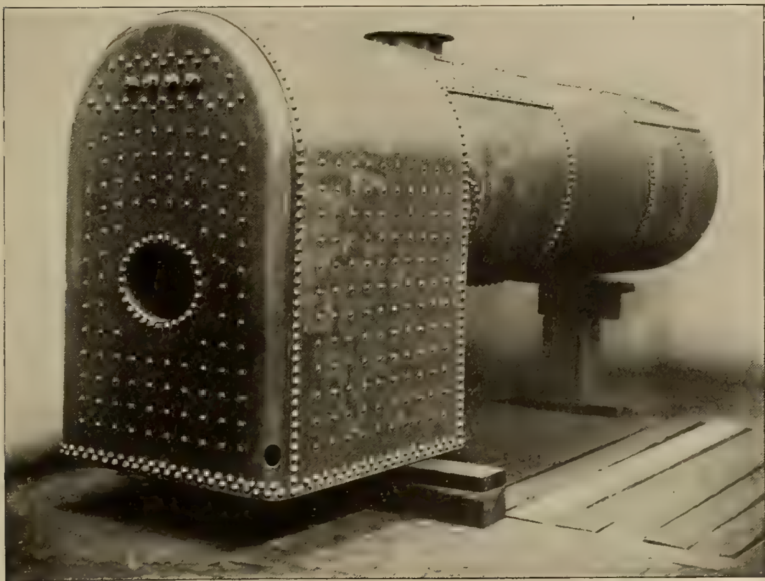


FIG. I. A LOCOMOTIVE TYPE BOILER.

THERE is perhaps no department of steam engineering in which modern methods have more completely superseded the older practice than in the case of the locomotive - type boiler. Boilers of this class are now manufactured, in the true sense of that word, by modern machinery and appliances with an accuracy rivalling that of the component parts of the steam engine, and at a cost far below that necessarily incurred under the old system.

This desirable result has been very largely due to the extraordinary improvement, within recent years, in the quality of the material worked upon. And again, steel boiler-plates are now procurable, at ordinary commercial prices, of dimensions which render it possible to build up a boiler from a comparatively small number of plates, with a consequent reduction in the amount of riveted seam necessary to secure the component parts of the structure together.

Formerly, when facilities for rolling plates were not so developed as they are now, the cost of boiler-plates increased very rapidly with the size, and it was cheaper to make a boiler out of a number of small plates than from a few large ones. There was also a belief (even now not entirely dissipated among

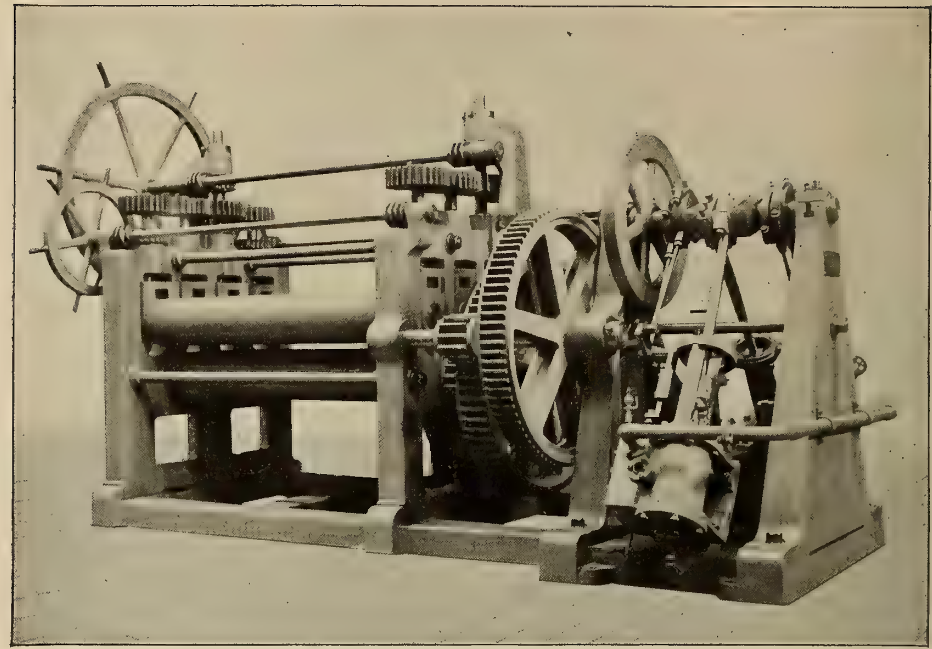


FIG. 2. A PLATE STRAIGHTENING MACHINE, MADE BY MESSRS. FRANCIS BERRY & SONS, SOWERBY BRIDGE, ENGLAND.

the older workmen) that the riveted lap joint was actually stronger than the solid plate. These two facts may probably account for the extraordinary amount of riveting to be found in old boilers.

Before proceeding to describe the various operations involved in the construction of the boiler, we may diverge for one moment to notice how very little the form of the locomotive boiler has changed since its original inception, now nearly seventy years ago. Taken as a whole, it may be said that the general design remains practically unaltered, while the detail has been improved in such a manner that, weight for weight, the factor of safety is probably doubled as compared with an old

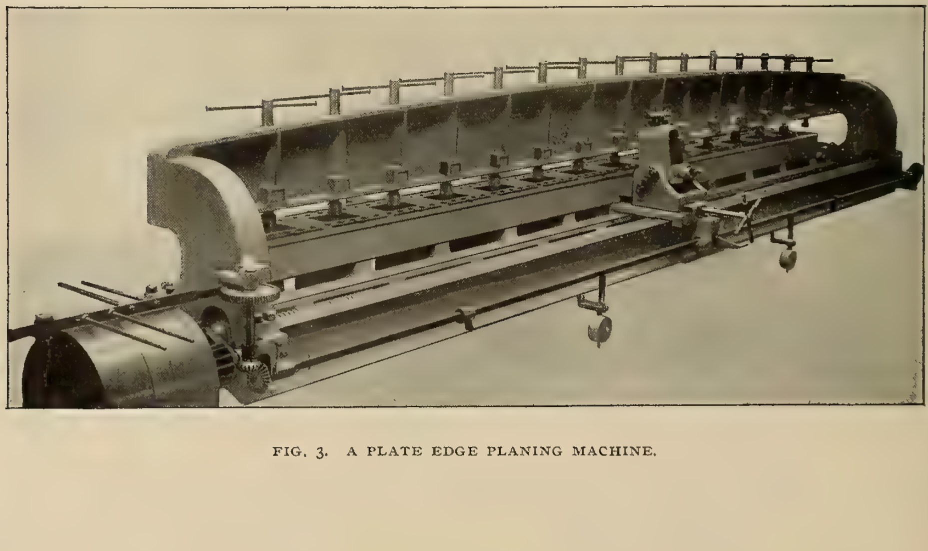


FIG. 3. A PLATE EDGE PLANING MACHINE.

boiler of similar size and intended working pressure.

This has been brought about by several causes in addition to those already mentioned, viz.: — The longitudinal seams in the barrel of the boiler are butt-jointed (and strengthened by probably both inside and outside covering strips, these again being double-riveted), thus preserving the circular form With the old lap-joint, the cross section of the barrel might be described as a circle with a flat place in it, which, under the strain of internal pressure, of course became distorted. Again, by a more judicious system of staying the flat plates of the boiler, the strength of the various parts has been equalised. For a certain test pressure the strain per square inch of section is now, for a given material, very much the same in all parts of the boiler. We do not now meet with the same riveting in circular seams as in longitudinal, the elementary fact that the strain upon the latter is double that of the first-named being pretty generally recognised.

Once more; it is now customary to make all but very small locomotive boilers flush-topped, that is to say, like Fig. 1, in which, as will be seen, the semi-circular top of the firebox shell is struck to the same radius as the barrel. Older boilers were very generally made with the firebox shell four or five inches larger all round than the barrel. Obviously this set-off, or departure from the straight line in the longitudinal section of the boiler, was an element of weakness.

Nowadays, the longitudinal stays are always straight, screwed rods, sometimes having enlarged ends, so that the sectional area at the bottom of the screw-threads equals that of the plain rod. These stays are passed through both ends of the boiler, and are secured by deep nuts inside and outside at both ends. In this way each stay is made to take its own share of the strain. Formerly the plan generally adopted was to rivet a piece of T-iron horizontally across each end inside, the stays being formed with a double joint at each end and secured by a pin, or cotter, dropped in. It is conceivably possible that four or six stays, fitted in this position side by side in a boiler, might have the total strain equally distributed between them, but it is very unlikely that this would be so. Inspection of many old boilers has revealed that the strain

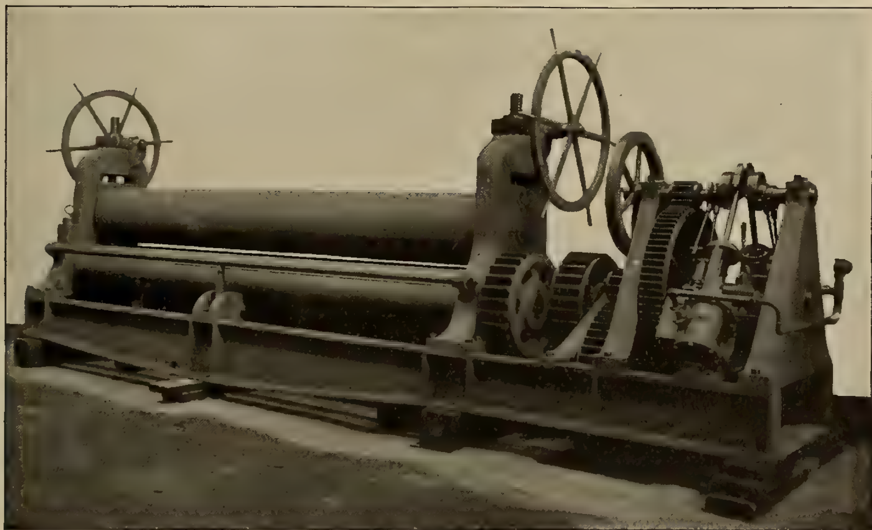


FIG. 4. ONE OF MESSRS. BERRY & SONS' PLATE BENDING MACHINES.

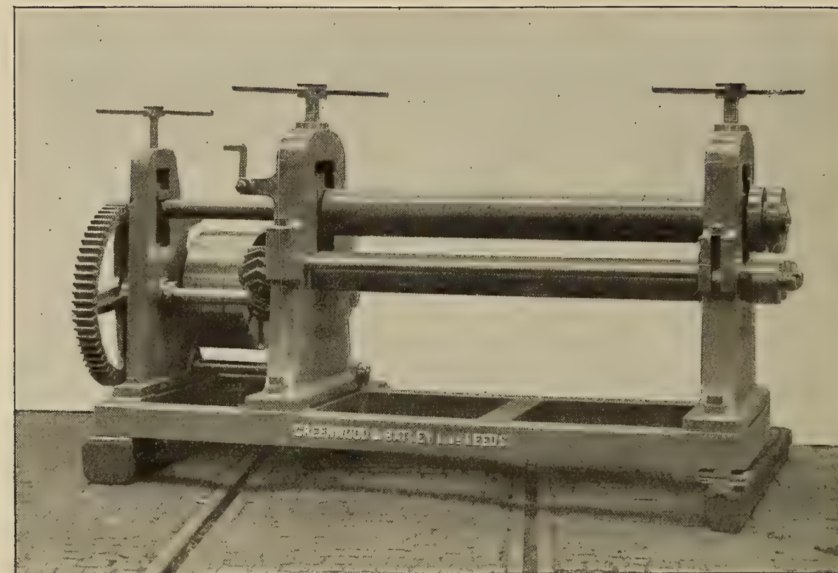


FIG 5. ANOTHER FORM OF PLATE BENDING MACHINE.

originally sustained by perhaps one or two of the stays only has been sufficient to bend the pin, or pull the welded joint asunder; or that one or more of the pins had disappeared altogether.

The steaming power of locomotive-type boilers has been much increased by a reduction in the number of the tubes,—a paradoxical assertion until we observe that at one time it was the practice to crowd as many tubes into the barrel as the tube-plate at the smoke-box end could possibly contain, the spaces between contiguous tubes being so narrow that the ascending currents of water could hardly make their way between them. A boiler has been known to benefit considerably by the removal of every third tube. Tubes nowadays are always spaced in vertical rows, giving thus ample opportunity for the ascending currents of water.

But the greatest improvements of all have undoubtedly been the substitution of drilled rivet-holes for punched ones; of hydraulic flanging in place of the archaic system of beating the plates into shape with wooden mallets; and hydraulic or machine riveting, as against hand work. Rivet-heads would sometimes fly off, one after another, from the seams of a boiler under the hydraulic test, owing to the combined effects of distortion from bad staying, and crystallisation of the rivet head and shank, caused by excessive hand-hammering.

There are many other details which might be noticed, but it will suffice to say that every part of a high-class locomotive boiler has been the subject of the most careful research. Design, material and workmanship are all the best of their kind, while equal skill has been exhibited in the methods of manufacture, so that the highest excellence should be obtained at a reasonable cost.

We will now, as briefly as possible, follow the fortunes of a set of plates, supposed to have been delivered, cut to dimensions, tested, and generally in accordance with the standard specification for this particular size of boiler. We will suppose that this boiler is one of a batch going through the shop in the ordinary course, for boilers cannot be made simply without incurring a good deal of extra expense. They must be made in dozens or in half-dozens, or, if of large dimensions, in not less than three of one kind at a time, to secure real economy in production. It should

also be noted that the various machines and tools should be so situated in the building that there is no useless carrying backwards and forwards of material; the work must proceed uniformly onwards, and the finished boilers should leave the shops at the opposite end to that at which they originally entered in the form of plates and bars. Further, the means of communication in the shape of overhead cranes, hydraulic, or otherwise power-driven, should be amply provided, or much time, both of men and of tools, is wasted in waiting for the transport of material.

But to return to our plates! It being understood that these have been cut by the makers to very nearly the finished dimensions to which they were ordered, the first thing to be done is to flatten or straighten them. The laborious process of straightening large plates by hammering is seldom resorted to in first-class practice, the usual method being to pass them through a set of rolls, which may be either the ordinary bending rolls (see Figs. 4 and 5), or a specially-constructed plate-straightening machine (see Fig. 2).

This apparatus consists usually of seven rollers, four of which,—the upper ones,—are adjustable as to height, and revolve only by contact with the plate, and three lower rollers, all driven by open-gearing. A crooked or buckled plate, being passed two or three times between these rolls, will be so nearly levelled that no further correction is needed for ordinary purposes.

FIG. 6. A HYDRAULIC FLANGING PRESS.

When any of the ordinary bending rolls are utilised for straightening purposes, they are first so set as to give the plate at the first pass a decided curve, or camber. It is then turned over, and, at the second pass, emerges with the curve reversed. The top roll

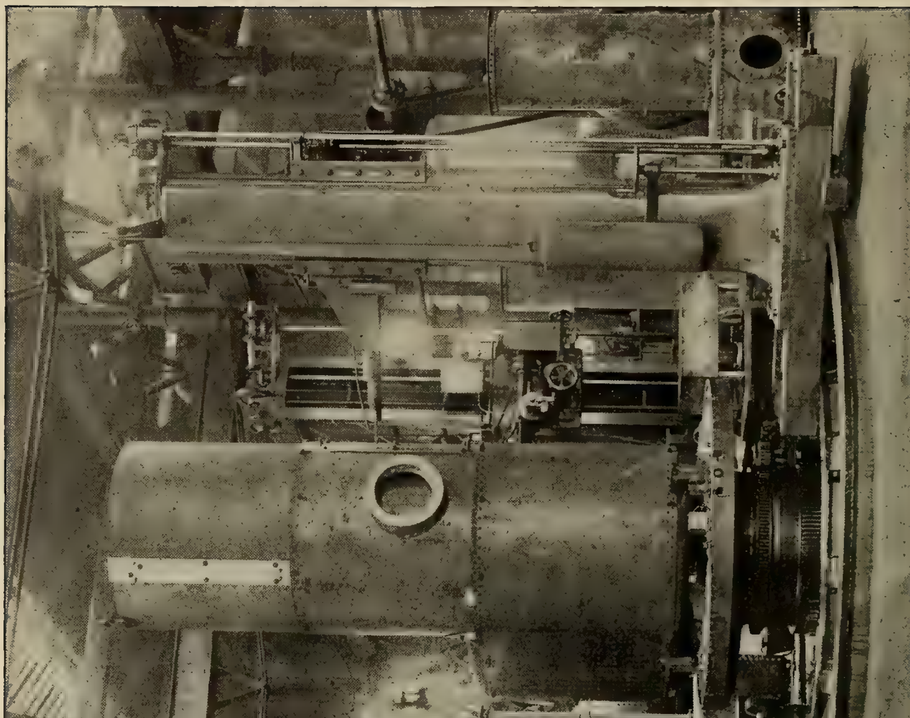


FIG. 7. A BOILER SHELL DRILLING MACHINE.

is then slightly raised and the plate is passed through a third time, when, if the operation has been conducted with judgment, a fairly level plate is the result. Small plates are usually levelled by hand upon the flat surface of a cast iron block by repeated blows of a hammer, the proper manipulation of which demands an uncommon amount of skill on the part of the workman, the principle being that of stretching the unbuckled part of the plate, so that the actual kink or wave in the plate which it is desired to flatten is exactly the one spot upon which the hammer must never descend.

Angles, and section-irons of various kinds, are straightened by being squeezed or pressed at the proper points in a machine having a reciprocating ram opposed by two abutments at some little distance on each side of it, and the same machine is employed for bending bars to a curve, except in the case of hoops or rings, which are bent between approximately shaped rollers.

After being straightened, the plates are separated into two divisions, viz., those which are to be flanged, and those which pass directly into the hands of the marker-out. We will trace the progress of the latter group first, taking it for granted that the two rings of which our barrel is composed are cylindrical and not conical, and bent up from plates of rectangular form. For each of these plates there is a full-sized steel template, in which every hole required, whether for riveting or other purpose, is laid down; and the template being clamped down upon the plate to be marked out, a circular steel punch, fitting the holes in the template, and terminating in a point, is laid in every hole. A light tap with a hammer leaves a centre-dot in the plate, into which, later on, the point of the drill will enter. The tacking-holes, or small holes for the purpose of temporarily securing the plates in position when building up the boiler, are now punched at regular intervals along each seam, being afterwards enlarged by drilling to regular rivet-holes.

The plates, having been marked out, are next forwarded to the edge-planer, an example of which is given in Fig. 3, by which all four edges are truly squared up to dimension, and parallel to the lines of rivet-holes, as marked out. The plates are clamped to the edge of a long table, along which a travelling tool-box is moved by a revolving screw. These machines are furnished with reversible toolholders, which turn the tool round at each end of the cut, and so save the lost time of the return stroke. The edges are not planed quite square to the plate, but slightly bevelled,—to an angle of one in eight.

The bending rolls consist of three large and heavy rollers of cast iron, wrought iron or steel, two of which are driven, while the third—the top one—revolves only by contact with the plate itself. This upper roll is so arranged that one of its bearings, or housings, can be readily swung on one side, and the roll itself lifted to allow of the removal of a plate when bent to a closed curve, such as a boiler-barrel ring. A moment's consideration will show that some means other than the rolls must be adopted for bending the last few inches of any ring. Suppose the bottom rolls to be ten inches in diameter, and allowing that they revolve only just clear of each other, the first and last five inches of the plate under treatment cannot be bent. These ends are, therefore, pressed to an arc of the proper radius beforehand, by hydraulic pressure, between a pair of dies, without heating the plate.

In large-sized rolls an independent steam engine is employed, but whatever the method of driving used may be, it is necessary that the stoppage and reversal of the rolls shall be under the most exact control. Many passes backwards and forwards are required, and by careful manipulation of the machine complete rings (after the ends have been separately curved as just described), the arch-plate of the firebox shell (which consists of two flat sides connected by a semi-circle), and the covering plate of the firebox (where the flat sides and convex top are connected

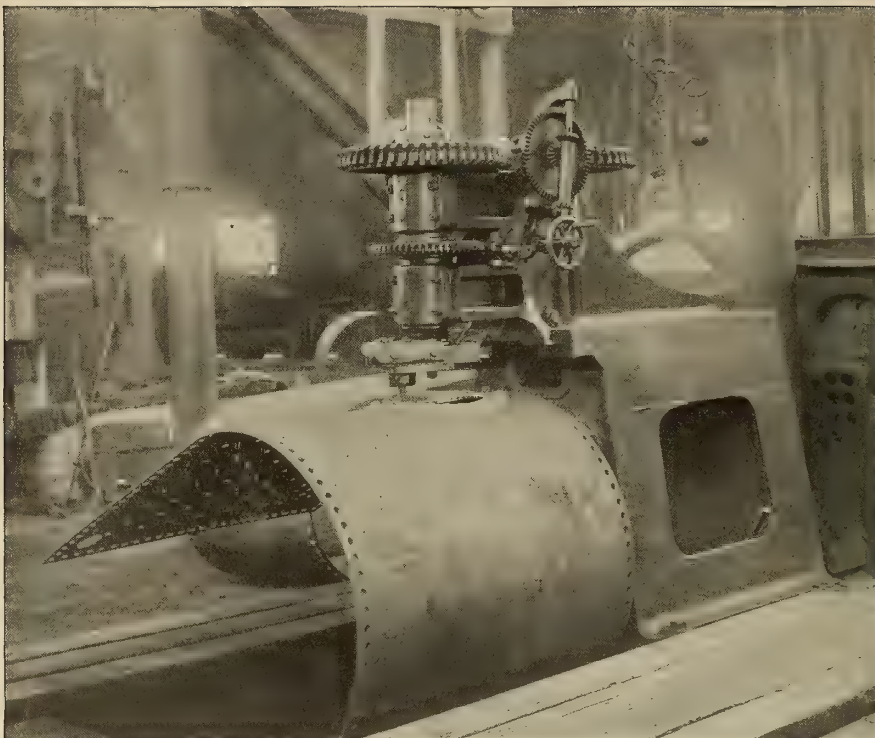


FIG. 8. AN OVAL TURNING MACHINE.

by corners, bent to a comparatively small radius), can be rolled to the desired form and dimensions with considerable exactness.

We must now turn our attention to the flanging-plates, which, in the boiler before us, are six in number, viz., the front or firehole plates of the internal firebox and of the firebox shell, the firebox tube-plate, the throat-piece or saddle, forming the back of the firebox shell, the circular smokebox tube-plate and the smokebox door.

The hydraulic flanging press, as will be seen from Fig. 6, consists of a massive foundation, or bedplate, connected by a pillar at each corner with an almost equally massive crosshead at the top, which forms the fixed abutment of the press. Upon these pillars, as guides, rises and falls, in obedience to the touch of a lever, the hydraulic platform. One of the dies, the block, over which the edges of the plate are pressed, is affixed face downwards to the top casting, or crosshead of the machine. The other die, the matrix, which is merely a hollow frame, corresponding in shape and size to the upper die or block, is attached to the rising platform by four short pillars, about eighteen inches high.

Now, we will suppose a red-hot plate out of the furnace to be lying, properly adjusted as to position, upon the lower die. The first thing which occurs is that this plate is swiftly lifted up by a miniature rising platform (which we have not before noticed) and nipped tightly against the inverted upper block. In another moment, with no sound except a gentle hissing noise, the main platform has risen, and is quickly pressing the edges of the plate all around to the contour of the block. Down comes the platform again, leaving the plate, now flanged, apparently sticking to the upper die, and we then see that the subsidiary platform by which it is held up is actuated by four small hydraulic rams,

passing through, and quite independent of, the main table. These nipping rams, as they are called, are now lowered, the flanged plate drops off the block, and is laid on one side.

In this manner are flanged, in sets of six or twelve at a time (to avoid the comparatively heavy cost of lifting in, fixing, and adjusting the dies), the circular tube plate, the square tube-plate (or firebox back-plate), the front-plate, and the smokebox door, this latter being merely dished to a slight convexity and not really flanged.

There are two more plates to be treated, which call for some further manipulation by the flanging-press. The front-plate of the inner firebox, in addition to being flanged around three of its bounding edges, requires pressing or bulging outwards round the firehole, so that only a comparatively narrow ring is required to effect the junction with the corresponding plate of the external firebox or shell.

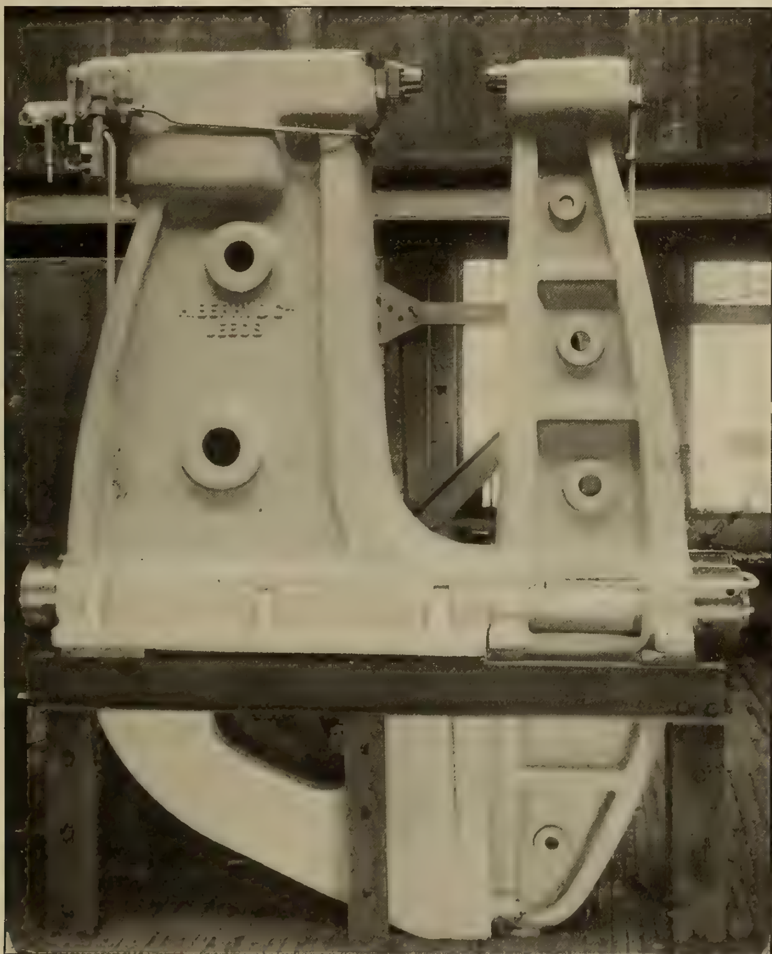


FIG. 9. A STATIONARY HYDRAULIC RIVETER.

This bulging-out of the plate round the firehole is effected by the nipping rams just mentioned, armed with a suitable die, at the same time that the outer edges just mentioned are flanged by the

rising of the main table, as before described.

The other special plate to be flanged is the saddle or throat-piece, two sides of which are flanged backwards to meet the sides of the firebox shell, while the concave curve which joins up to the under side of the barrel is flanged outwardly, or forwards. This would be rather an awkward plate if dealt with by itself, but by taking a plate large enough to make two such throat-pieces, and cutting a large hole in it at the centre of its length, the flanging is easily done at one operation, and the plate is afterwards cut in two across the centre, forming two complete throat-pieces. All these flanged plates have now to be machined at the edges as no raw or untooled edges can be permitted either inside or outside of the boiler. The smokebox tube-plate is, of course, turned, the square plates are planed, and the front plate, which is square with a semi-circular end, is treated in a special machine.

The next operation is plating, or building up the separate plates into the form of a boiler. All the plates, together with the foundation ring, firehole ring, roof-stays, etc., are delivered by trolley to a gang of platers, who put the boiler completely together by means of bolts inserted into the small tacking-holes already mentioned, it being noted that these are the only holes yet to be seen in the plates.

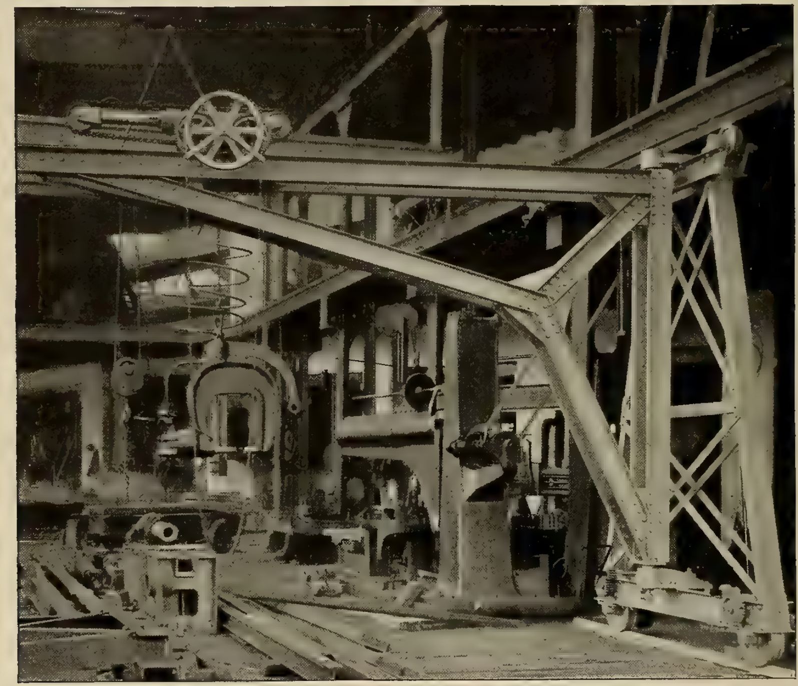


FIG. 10. SINGLE-RAIL CRANE WITH HYDRAULIC LIFT AND PORTABLE HYDRAULIC RIVETING MACHINE, MADE BY MESSRS. HENRY BERRY & CO., LEEDS.

The boiler shell is accurately levelled and squared, the butt-strips for the longitudinal seams are fitted on, the position of all the various mud and man-holes is marked off, and the whole structure is rigorously examined and criticised by the foreman of the department. All being found satisfactory, the boiler is separated again into three main parts, viz.:—

(*a*) The complete outer firebox shell

with one barrel-plate, and the foundation ring.

(*b*) The inner firebox.

(*c*) The remainder of the barrel with the circular tubeplate and the smokebox front.

These are all taken off to separate drilling-machines, specially adapted to their particular requirements. Each of these merits a few words of description. Fig. 7 shows a large machine, having a horseshoe-shaped track or bed (*i. e.*, two flat sides connected by a semi-circle). Two of the drilling heads traverse the flat or straight portions of the bed, while a third head moves round upon the curved portion.

The boiler shell to be operated upon is placed on end, with the barrel part sticking upwards, and it is thus possible to drill all the rivet-holes except those around the bottom of the firebox, the drilling-head which moves upon the curved part of the bed being fitted with a very long arm and drill-spindle, which enables it to reach the row of holes around the throat-piece where it joins the barrel.

The machine illustrated is capable of dealing with the largest locomotive boilers ever constructed, and is entirely under the control of one man, whose time in keeping all three drilling-heads in full operation is pretty fully employed, as a very few seconds are occupied in drilling through the two, three, or four thicknesses of steel plate which are met with in different parts of the boiler shell. While this is going on, the inner fire-box is being similarly treated at another, but much smaller, machine of similar construction, but with four drilling heads, one for each side of the firebox, the tube-holes in both tube-plates having been previously bored in a double-headed machine with vertical spindles.

The outer and inner fireboxes are now united, and the foundation ring, formed out of a solid bar, and the fire-hole ring, which has been surfaced on both sides in a special oval-turning machine, illustrated in Fig. 8, are bolted in position. The portion of the barrel which we have seen drilled at its junction with the shell is now removed, and the two fireboxes, one within the other, are now set upright in their natural position on the bedplate of one of the machines, to be drilled for the double-riveted foundation-ring joint, and for all the screwed firebox-stays, all these being drilled straight through both boxes at one setting.

The barrel, now temporarily put together, with all its butt-strips, inside and outside,—and raised flanged manhole mouthpiece with its strengthening ring,—with the circular or smokebox tubeplate in position, has been already drilled at another machine, this time with two heads only, the barrel being suspended while drilling from a hydraulic crane overhead, instead of being fastened down to a bedplate as in the previous cases. The whole of the plates composing the different structural parts of the boiler are now separated, and, the small burrs, left from the drilling, having been removed, are ready for the annealing furnace. This is simply a large oven, in which plates, sufficient for several boilers, can be stacked at one time.

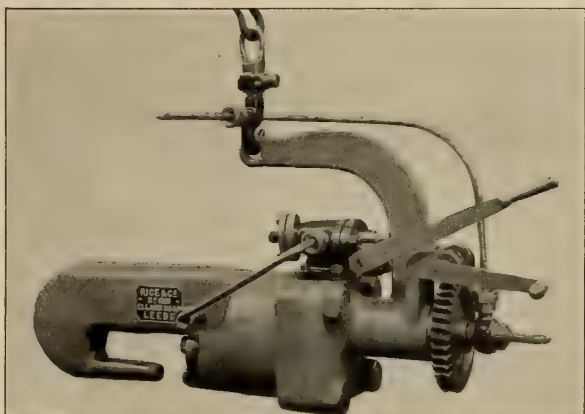


FIG. 11. A PORTABLE HYDRAULIC RIVETER, MADE BY MESSRS. RICE & CO., LEEDS, ENGLAND.

These are brought to a cherry-red heat, after which the fire is allowed to die down, and the plates are left to cool gradually during a period of thirty-six hours. This process having been accomplished, the plates are ready for their final reassembling. They have come out of the annealing furnace with all the small local strains induced by bending, rolling, thinning corners, etc., taken away, and having a dull red colour.

The outer firebox or shell is now once more tacked together by bolts, here and there, and conveyed to a riveting machine, over which it is suspended by a hydraulic crane. By the use of an appliance of this kind four or five red-hot rivets can be put in place at once,

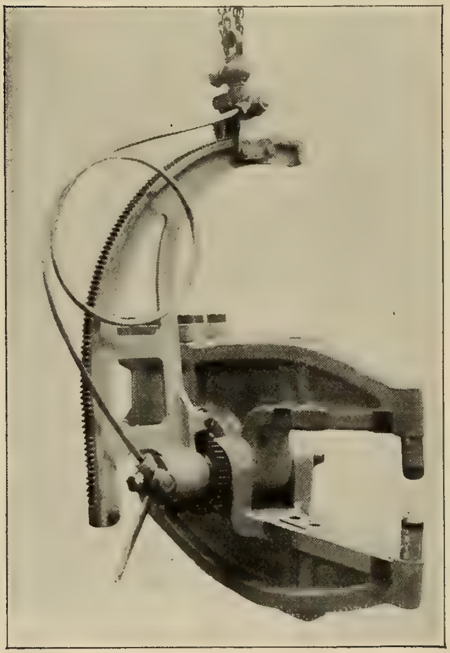


FIG. 12. A SPECIAL BOILER RIVETER MADE BY MESSRS. MUSGRAVE BROS., LEEDS, ENGLAND.

and closed by the machine almost before the red has passed out of the first one.

The front-plate is, of course, riveted around first of all, and then the throat-piece, after which the first ring of the barrel is put in, and its longitudinal seam (with its inside and outside covering-strips) tacked by a rivet here and there, in order to keep the barrel in shape, while the circular seam uniting it to the firebox shell is riveted. Before working around a circular seam of this kind it is usual to first insert four or six rivets at equal distances around, and then put in the remainder of the rivets, otherwise there is a tendency to "gather" a little as each rivet is closed, so that the last few holes would fail to coincide. This is caused by the tremendous pressure upon the rivet-heads, which has the effect of slightly elongating the spaces between the rivet-holes. When the second barrel-plate is riveted on, the circular tube-plate is put in, tacked, and riveted.

The shell is now ready for the firebox. This has been already riveted up by another machine and has been completed by attaching the bridge-stays. These are formed, each, of a pair of long narrow plates, riveted together, with distance-pieces between, and properly fitted so as to rest fairly upon the corners of the firebox. The roof or crown of the box is held up to these stays by square-headed iron bolts, secured by nuts screwed up from inside the firebox. Under each nut is an asbestos washer, and under each head a square iron plate spanning the pair of girders and firmly clipping them together.

The boiler is now all but complete. The outer shell is entirely riveted up, and the firebox is dropped into its place and secured by temporary bolts through some of the rivet-holes. At this stage the boiler is picked up and removed to another part of the shop, where it is dropped upon its back, or upside down, under a portable riveting machine, which is slung from a hydraulic crane overhead.

This handy tool, one form of which is shown in Fig. 10, is known as the "lobster", from a fancied resemblance to that marine animal, and the name gives a very fair idea of its action. The lobster works its way round the foundation ring and the firehole ring very quickly, and is then moved away to

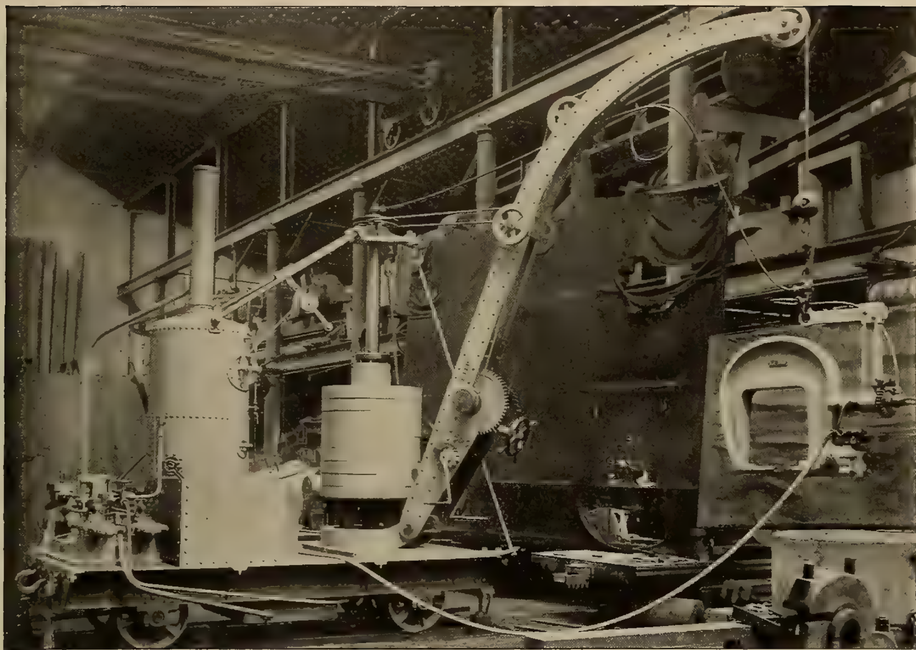


FIG. 13. ANOTHER FORM OF PORTABLE HYDRAULIC RIVETING PLANT SUPPLIED BY MESSRS. HENRY BERRY & CO.

another boiler, leaving our boiler free for the next operation of staying.

The screw stays are screwed in by hand, after the holes are tapped, in preference to the use of a machine for the purpose for the following reason. Although these stays, of which sometimes hundreds go to a boiler, are screwed, or rather chased, by special machines, yet occasionally one meets with some which are screwed a shade too small. There are also minute differences, even in Whitworth taps, and again, a new tap is larger than one which has been in use for some time. A stay-screwing machine would screw in slack or tight stays indifferently; but if screwed in by hand the slack stay can be detected immediately and can be rejected.

The projecting ends are then cut off and cold-riveted over. All the seams, inside and outside the boiler, are gone over either by a pneumatic caulking hammer, a little machine which is said to strike ten thousand blows per minute, or, in the case of seams where this pneumatic tool cannot be brought to bear, by hand hammer work in the usual way, the tool used in either case being of such a breadth that the term "fullering" perhaps better describes the operation. Any rivets which need it are trimmed round, and the boiler is ready for tubing.

The boiler is then again picked up and conveyed to the testing bay, and dropped upon stools, so as to bring the tube-holes at a convenient height for working. The tubes are now inserted, both ends expanded, and the firebox-ends headed over, no ferrules being used, unless specially ordered. Many engineers cling to the ferrule, but no reason has been seen to regret its discontinuance for now many years past.

The tube-setters also put in the longitudinal stays, of which there are three in the boiler before us, and retire in favour of the tester. The boiler is again turned over upon its back, after temporary covers have been fitted in the manhole and mudholes, and the test

pressure from the hydraulic main is introduced.

The usual proof test is 100 pounds above the intended working pressure, which, in the present boiler, is 150 pounds. Testing to an excessive pressure, though sometimes insisted upon by consulting engineers acting as boiler inspectors, is to be deprecated, as affording no useful information, and possibly even permanently injuring the boiler.

Not a drop of water must be visible externally after the test pressure has been on for twenty minutes. Roof deflection must not exceed $\frac{3}{32}$ inches. This is seen to by the foreman of the department, who is required to sign a certificate to that effect, and our locomotive boiler, now built and completed, is either sent into the erecting shop to be fitted up and steamed, or passed into the yard and booked into stock.

HIGH TEMPERATURES ABOARD SHIP.

By F. M. Bennett, P. A. E., U. S. N.

A partial reprint of an article entitled "Reconstructed American Monitors," originally contributed to the *Journal* of the American Society of Naval Engineers.

ERICSSON conceived the monitor type of vessel for coast and harbour defence only. He described his invention as a raft for carrying a fort, and he had no expectation of its being used as a cruiser or going to sea at all except to transport its fort along the coast to the point to be defended. The performances of the first *Miantonomoh* and *Monadnock*, of the United States Navy, in making long sea voyages were valuable, because they proved the sea-worthiness of the type and stopped a great amount of carping, but this was achieved at great price of human labour and suffering and should not be imitated, even by the improved monitors, except under the spur of actual military necessity. Full confidence in the sea-worthiness of monitors does not exist yet, in spite of their records.

When the North Atlantic squadron, of the United States Navy, was caught in the great storm off Cape Hatteras last February, the monitor *Amphitrite* was compelled to heave to by the really appalling masses of water that boarded her, and thus was lost sight of by the other ships during a very wild night. Her absence caused such anxiety that, when day broke, the cruisers *New York*, *Maine* and *Columbia* were dispersed over that part of the ocean seeking for her, and her ultimate discovery in an undamaged condition, jogging along toward the point of destination, was a source of relief and joy. Except for a whale boat crushed by a sea, she passed through the ordeal practically uninjured, though men were lost from both the *Maine* and *Marblehead* and both those ships suffered serious damage. The *Amphitrite* was not a pleasant home during that period, however.

The *Amphitrite* was put into commission on April 23, 1895. Stores, ammunition and equipment were put on board, the perfunctory and inadequate dock trial was observed, and on May 9, sixteen days after going into commission, she got under way and steamed slowly to an anchorage inside of Cape Henry. A navy yard tug, in readiness to render aid in case of breakdown, accompanied us as far as Fortress

Monroe and a number of navy yard mechanics were on board to that point. The next morning we got under way and very soon encountered a defect in organisation that put the ship in real peril and made the immediate hauling of all fires necessary, because of ignorance in the fire room.

The supply of water to a boiler under steam is an important matter; so vital in fact that, on shore, laws and licenses generally prohibit inexperienced persons from endangering the neighbourhood by attempting to do it, though the explosion of boilers in saw-mills and on farms is frequent enough to keep the reading public informed of the natural result of incompetence in this regard. When a number of steam boilers is cramped into a dark and limited space on shipboard, and the problem is further complicated by the use of salt water and the uncertainty of water level due to rolling, the service becomes so serious that nerve, knowledge and experience are requisite on the part of the water tenders to protect the ship and its crew from sudden destruction. Under no circumstances can a boiler explosion have such frightful possibilities as at sea, and for this reason the greatest precautions should be taken to ensure vigilant and capable boiler attendants for ship service.

In apportioning a crew for the *Amphitrite*, the engineers' force was reduced by dispensing with water tenders, the blacksmith, boiler maker and coppersmith being ordered to assume their duties; this perhaps on the supposition that a mechanic is an interchangeable being without specialty in trade. The fact is, however, that the trades mentioned, even that of boiler making, have no earthly connection with the management of boilers, and artisans representing them are no more to be expected to know how to control boilers under pressure than coopers, clock makers or moulders might be. The defect was not developed by the few hours' steaming from Norfolk, with navy yard men and the greater part of the regular force in the engine and fire rooms to assist at the first working of the machinery under way, but it appeared at once when our force went into regular sea watches. A trivial cause (hot feed water) interfered with the action of the main feed pump, and as this was not remedied or other pumps put in use by the "water tender," who happened to be the boiler maker, the water in the boilers gradually disappeared without exciting his interest.

Information of the trouble eventually reached the engine room through the medium of scared firemen, who knew the situation to be abnormal and dangerous. Hasty investigation developed the startling fact that the boiler maker had not been giving the slightest heed to the feed pump, and actually did not know that water should be kept up to a certain level in the boilers; equally startling was the conflicting testimony of men in the fire room, who differed from ten minutes to one hour in their estimates of the time when water had last been seen in the gauge glasses. Men from the watches off duty were summoned and all fires hurriedly hauled, perhaps not a moment too soon; pressure was then reduced, tube sheets examined, water pumped up in the boilers, and fires started again after a loss of about two hours. The three official water tenders were forthwith removed from duty and their places filled by old firemen, who, though sorely spared from the fires where they belonged, knew something about tending water. Discipline was somewhat perverted by putting the mechanics on watch for instruction under these firemen, their juniors in the military classification of enlisted men. Two of these three mechanics had never been to sea before and became useless from seasickness, besides being utterly ignorant of water tending. After several months' experience they became habituated to sea life and learned to manage the boilers satisfactorily. During those months, instead of adding to the working force, they actually reduced it by the three firemen diverted from their proper labours.

The ship proceeded at once to Savannah, a distance of nearly 500 miles,

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THE UNITED STATES MONITOR "AMPHITRITE."

at such a moderate rate that ninety-eight hours elapsed from port to port; complete cessation of progress was avoided on the last two days only by the liberal use of streams from the fire hose on the crank pins. This is probably the first instance of an untried monitor being sent, without convoy, on a long sea voyage in the season when bad weather is to be expected; it is certainly very unusual for any naval vessel to take the sea so soon after going into commission. A number of faults were developed about the machinery, particularly in the matter of bulkhead and other steam joints, which were so old that many gave way under prolonged use. The crank pins and main journals were subsequently found badly pitted, probably by galvanic action during the years that the engines lay idle. Owing to the short time the ship had been in commission, the men were not very familiar with the machinery and pipe connections, and this, added to the defects that developed and the discomfort caused by rough weather, made the trip a trying one, particularly for the chief engineer and his one assistant, who alternated in four-hour watches the whole time.

The first trip of the *Amphitrite*, with battle hatches and superstructure doors closed to keep the seas out, brought up the question of internal temperatures in a very painful manner. The temperature of the outside air varied with latitude and with day and night from 50 to 72 degrees, but, even with this cool atmosphere, the engine room ranged from 120 to 140, and the fire room from 140 to 160 degrees. This seemed severe and some of the men broke down under it, but events proved it to be only a mild foretaste of what was in store. After about three weeks on the southern coast we returned north, having bad weather again off Hatteras and going through the same chapter of discomforts experienced on the way down, except that the ship was hotter because the season was advancing.

At Hampton Roads, the Board of Inspection and Survey examined the vessel, and the full power steam trial required for that inspection brought more trouble. The day (June 25) was very hot and still, impairing the furnace draft, which was wretched at best, and imposing great discomfort upon the engineers' force because of heat below. On the working platform of the engine room, the thermometer ranged from 138 to 158 degrees during the afternoon watch when full power was attempted, the working gear being so hot that it could not be handled without gloves or hand rags. The fire room varied from 157 to 170 degrees. Under such conditions nothing like the maximum steam pressure could be maintained, and the full power effort resulted in a mean speed of 7.27 knots for less than two hours. When the call to general quarters sounded, the steam pressure was far below that required to produce the hydraulic power needed to work the turrets, and was obtained only by stopping the main engines, as described by the following extract from the steam log of that day :—

* * * "Ahead full speed at 1.38. By this time it was found impossible to keep up steam on all six boilers at more than about 45-50 pounds with the force on watch and keep the main engines running at full speed. Eight members of the engineers' force are on the sick list; two men of this watch were overcome by the heat before 1 P. M. and put on sick list; all the firemen and coal passers of one watch and three of another are now in the turrets at gun stations for general quarters, leaving four firemen and four coal passers only to work all the furnaces in the ship. The steam pressure being insufficient to work the turret-turning mechanism, the state of affairs was reported to the commanding officer, and by signals from the bridge the main engines were stopped or run at slow speed for 25 minutes from 1.48, by which resort sufficient steam was raised to operate the turrets, and target practice was proceeded with."

The great gun firing was reported as very successful. Nevertheless, had the action been real instead of simulated, the delay of 25 minutes in getting up

steam might, and probably would, have been fatal. In this case, lack of men in the fire room was the direct cause of the guns being powerless for a period long enough to have permitted a much weaker foe to disable or destroy us. The object in taking men from the fire room force to swell the gun divisions at drill is said to be to create a reserve force familiar with the working of guns, to draw upon to fill vacancies in battle. As a general proposition, it may be safely advanced that the fireman will render the best service and contribute most to the fighting efficiency of his ship if he keeps up steam on the boilers. At best he gets small knowledge of gun drill. The firemen of the *Amphitrite* detailed for the turret crews were stationed in the magazines and handling rooms to get out ammunition, and were completely separated from the guns and exercises of the turrets. I frequently questioned these men as to their stations, and in a period of two years failed to find even one who had ever been stationed in a turret or given any instruction in the working of the guns; this, too, when they were accustomed to handling machinery and, therefore, especially qualified to readily learn the mechanical work of operating such guns. In many ships it is the practice to draw heavily upon the engineer division to increase the powder division. Men so detailed are as remote from the guns as though they remained in the fire room, and they gain no knowledge of the working of the battery.

The great internal heat that rendered the *Amphitrite* inefficient was due to lack of provision for ventilation in the engine and boiler spaces. These regions became so hot that little useful work could be done in them, and the lack of air was such as to actually ruin the furnace draft, smoke coming out freely from the holes in the furnace doors. Aside from two small ash hoist tubes in the central part of the fire room and a small escape hatch forward, there were no openings from the fire room to the outer air. One of the ash tubes was the mast and had a cap at the top; the other had a revolving cowl at the top just abaft the smoke pipe, and shut off from any beam winds by boats stowed on each side of it. The escape hatch opened under the bridge and was surrounded by the conning tower, the mast, hammock nettings and other deck fittings. Two blowers on the forward engine gallery drew air from an armoured tube and discharged it into the fire room or into the engine room, or both ways, according to the arrangement of the dampers, the latter being the usual practice. The very successful regenerative principle upon which this blower circuit was designed and constructed will be described further along.

The boilers reached nearly to the iron main deck of the vessel, and as the air above them and between the deck beams had no escape, it became greatly heated and lay roasting in those spaces. It was impossible for a man to go on the gratings behind the upper parts of the boilers after they had been under steam a few hours, though the main and auxiliary stop valves were there. A board of officers that reported on temperatures in the vessel got at this place only by introducing a thermometer on the end of a long pole, and this thermometer, when fished out and taken to a place where it could be read, showed 202 degrees.

The superstructure containing the cabin and ward room was directly above the engine and boiler rooms, with a light wooden floor laid over the iron main deck. At sea, with the doors closed, this habitation became exactly like a frying pan on a hot stove lid. The smoke pipe, partly uncovered for alleged ventilating purposes, passed through the centre of the ward room and by vigorous radiation contributed its full share to the general discomfort. The deck, in spite of its wooden sheathing, was so hot as to be painful, and I hesitate to say from memory the temperatures the board reported as being usual in the rooms, in bureau drawers, on the ward room table and in other parts of the officers' quarters. It was as high as 112 degrees and I think

greater. Sleep was only a period of unconsciousness, induced by utter exhaustion, and was without restful quality.

The state of affairs was reported by the Board of Inspection and by the commanding officer, but before any action was taken, we were suddenly ordered to go to Brunswick, Ga., to drill a company of naval militia at that place. The trip of about 500 miles occupied five days in the latter part of July, and, for sheer suffering, has perhaps seldom been equalled in our naval history. The fire room temperature was never below 150 degrees and often above 170, while the engine room ranged closely about 150 degrees. For the first twenty-four hours the men stood it well, but on the second day seven succumbed to the heat and were put on the sick list, one of them nearly dying; before the voyage was ended, twenty-eight had been driven to seek medical attendance. The gaps thus created were partially filled with inexperienced men from the deck force, until there was only a life boat's crew left in each watch. The water gauges were defective, being constructed on a scientific principle too delicate for use with supersalted or impure water. By choking with salt they caused anxiety and danger, because the quantity of water in the boilers could not be accurately known, and their light spring valves, becoming clogged open, added to the misery of the fire room by blowing steam and hot water constantly. The uncertainty about water in the boilers kept the men in a nervous state of mind bordering on panic, and caused the hauling of fires from one or more boilers time after time, thus augmenting the infernal heat of the fire room. Under such conditions no fair steam pressure could be maintained, and all this pitiful suffering and toil resulted in progress of barely five knots.

On the evening of the fourth day out our men had literally fought with fire to a finish and had been vanquished; the watch on duty broke down one by one and the engines, after lumbering along slower and slower, actually stopped for lack of steam. The ship was allowed to drift in shore on the tide and was finally brought to an anchor in St. Simon's sound. Though a warship of formidable characteristics and sent on this distant service, it is doubtful if the *Amphitrite* could have gone into action at that time, or have steamed one hundred miles further to save herself. The responsibility for this must be charged to the faults in her construction and not to her crew, who, officers and men alike, exerted themselves to the utmost under the most trying and discouraging circumstances.

At daybreak the next morning we got under way and steamed at a very conservative rate to our destination, fortunately only about ten miles distant. The scene in the fire room that morning was not of this earth, and far beyond description. The heat was almost destructive to life; steam was blowing from many defective joints and water columns; tools, ladders, doors and all fittings were too hot to touch, and the place was dense with smoke escaping from furnace doors, for there was absolutely no draft. The men collected to build up the fires were the best of those remaining fit for duty, but they were worn out physically, were nervous, apprehensive and dispirited. Rough Irish firemen, who would stand in a fair fight until killed in their tracks, were crying like children and begging to be allowed to go on deck, so completely were they unnerved and unmanned by the cruel ordeal they had endured so long. "Hell afloat" is a nautical figure of speech often idly used, but then we saw it.

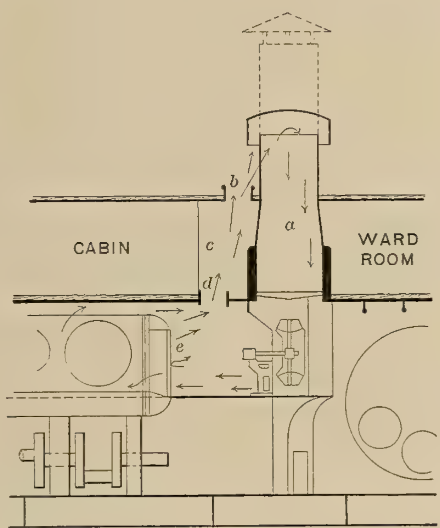
For a month thereafter the ship was actively employed on the southern coast, drilling naval militia at different ports and sweltering in the new dock at Port Royal. One trip of twenty-nine hours broke the record for heat, the fire room being frequently above 180 degrees. All fire room temperatures referred to in this paper were taken in the actual spaces where the men had to work, and not from hot corners or overhead pockets. We got back to Norfolk on the 23d of August, and though that place

THE U. S. MONITOR "TERROR" AT THE BROOKLYN NAVY YARD.

is notorious for heat at that season, it was a relief to us to get even that far north and let our overcharged engines and boilers radiate their heat at leisure. The ship had then been in commission four months, during which time the main boilers had been under steam forty-three days, and all our steaming had been south of the capes of the Chesapeake during the hottest months of the year. With the exception of two days in the Port Royal dry dock, we had always had steam on one, and sometimes two boilers, for run-

ning auxiliary machinery and turrets. So much for actual experience in a reconstructed monitor. Let us now look at the means by which the worst faults were corrected without appealing to the higher mathematics or abstruse sciences. Two boards, one composed of officers of the ship, and the other of members of the Board of Inspection and Survey, reported upon conditions as they existed, and the Navy Department authorised the principal changes that had been recommended. Four large ventilators with revolving cowls were put through the protective deck into the fire room, one in each forward corner and the others over the two after boilers. The ash-hoist tube, formerly screened by the boats and smoke pipe, was built several feet higher and fitted with two branches, one on each side of the smoke pipe. The latter was boxed in where it passed through the ward room. Two ventilators were also let into the top of the engine room, a previously existing uptake pipe with a close-fitting mushroom cap being utilised as the trunk of one of these.

The immediate effect of these additions was remarkable. By admitting outside air to the oven-like spaces over the boilers, the fire room temperature was reduced to a living figure, and the ward room deck above it ceased to resemble the top of a stove. The same improvement resulted in the engine room. This method of ventilation is the only one that appears sensible from the standpoint of the ship, no matter how scientific may be the theory of pumping hot air out of internal spaces. It does the men who work in those spaces no good to know that hot air is going out, when they can feel that it is well baked before it goes. By mingling the heated air below with cold fresh air from above decks, the general temperature is lowered and the resulting mixture fit to breathe. Furthermore it will make fires burn, as the change in the *Amphitrite* showed in a striking manner. Instead of smouldering furnaces we had bright steam-making fires, and, instead of painfully dragging along at four or five knots, our progress was increased from two to three knots, varying with the weather and state of the sea. A perfectly fair comparison was made possible, for, a year after our first trials on the southern coast, we steamed north from Key West in the latter part of June, touching at the same ports we had visited the summer before. On this voyage the engine and fire room temperatures were thirty degrees less than the year before, and the speed of the ship, which had been lying five months at Key West without docking, was fully two knots greater.



THE ENGINE ROOM BLOWER ARRANGEMENT ON THE "AMPHITRITE."

Another important change was made in the source of supply of air for the engine room blowers. The regenerative feature of the original arrangement has already been mentioned and may best be described by reference to the accompanying sketch, copied from a blue print showing the change that was made. The large air downtake *a*, armoured for four feet above the main deck, is located amidships between the engine and fire rooms, and originally extended about four feet above the superstructure deck. Two blowers on the engine room grating draw air from the tube and discharge it into the engine room or into the fire room, or both. The

top of the tube was capped as shown, the lower rim of the cap being about three feet above the hatch *b*. A small enclosed trunk *c*, in which there is a ladder, affords escape from the engine room through the hatch *d*. In operation, the air was forced against a hot steam chest cover *e*, directly in front of each blower discharge, and, after circulating about the cylinders and steam pipes, poured from the engine room through the escape trunk, to be drawn down the supply tube for another superheating circuit. The remedy for this blunder was not difficult; it was effected simply by removing the mushroom top and building the air tube about seven feet up into the air, as shown by the dotted lines. Thereafter the blowers discharged real air instead of a blast hot enough to have come from Tartarus. About a year after these changes had been found necessary on the *Amphitrite*, I noticed that the *Puritan*, not then completed, had the same faulty location of intakes for blowers, and that the absence of downcast ventilators was conspicuous.

Besides the benefits already enumerated as resulting from the changes in the *Amphitrite*, we found that the fire room force could stand several days under steam without breaking down. Previously we had never been able to take the sea with more than four of the six boilers in use, even with liberal help from the deck force. With the improved ventilation, we found we could keep five boilers in use without distress, and this raised the cruising speed to about nine knots. With that as the standard, she recently kept position in a large squadron of modern ships steaming from Hampton Roads to New York. In March last, off Charleston bar, she ran a full power trial for six hours without exhausting the men in the least; the average speed for that time was 10.72 knots, with wind, sea and current, estimated at one and one-half knots, against her.

The *Puritan* has been put in service with defects similar to those described in the case of the *Amphitrite*, and her experience thus far indicates that under similar conditions they would lead to the same disasters. In February of the present year, she steamed from New York to Charleston with six of her eight boilers at a rate varying from five to seven knots only, though in the winter season, her engine room averaged about 115 degrees and the fire room was from 140 to 152 degrees. Her chief engineer informs me that thirteen men of the engineers force were prostrated by heat during that trip. Had she gone on the southern coast in midsummer, as the *Amphitrite* did, the same suffering and loss of efficiency from heat must have resulted. Like the latter vessel, her machinery gave much trouble and in more serious degree, for she had to be towed the greater part of the distance from Charleston back to New York. While under her own steam on that voyage, she encountered a severe gale, and behaved in it in a manner to bear out the staunch, seaworthy reputation of the monitor type.

The *Miantonomoh*, unlike the others, has no superstructure over the engines and boilers. In the early part of her commission, in 1892, the highest temperature reached on the working platform in the engine room was 130, and in the fire room, 150 degrees. Owing to the discharge of vapour into the engine room from the feed tank, the air was almost saturated. The heat, moisture and absence of change in the air made very oppressive conditions. Later on, a hatch was opened direct to the air in the after part of the engine room, the feed tank was closed and provided with a discharge to the air, and a separate blower was put in for the ventilation of the working platform, these changes making a decided improvement. However, not being put on cruiser duty, she did very little steaming, and that always in northern latitudes; her possibilities for heat were, therefore, not fully tested. Like the *Terror*, her turrets are without barbettes, a serious fault not shared by the other monitors. The *Terror* has ventilators for her engine and boiler spaces and a good system of forced ventilation besides. The greatest fire room temperature thus far reported from her is 127 degrees, but the engine room has reached 129 degrees.

ENGINEERING EXPERIENCE.

By G. W. Dickie.

EXPERIENCE, in the writer's opinion, is the formative or moulding effect upon the mind of the thoughts that may pass through it from within, and all the impressions received by it from without, in regard to the work with which our lives are identified.

Memory must be a powerful factor in experience; in fact, the man of experience is such by virtue of the store of impressions which he has gathered and arranged in his mental storehouse in such order as to be readily available at the moment when their evidence is required to decide his course of action in regard to the subject to which these impressions relate.

When a plan or design for any engineering work is presented to an experienced engineer for his opinion as to its merits, or practicability from an engineering or commercial standpoint, a series of pictures at once present themselves to his mind. These are mental photographs of similar works, or works of the same character with which he has been connected in the past.

Where they succeeded and where they failed are clearly pictured to his mental vision, so that he will be able to readily compare these pictures with the proposed plans, and as the pictures of failures or successes most nearly coincide with the plans before him, so will his opinion be. This is experience, and it is this quality in an engineer that commands the highest price in the engineering market.

But, you will say, engineering is an exact science, or is every day coming nearer to it, and all problems in engineering are capable of demonstration, and if the past work of any engineer had been carefully figured out in all its details, these mental impressions in regard to the results of the finished work would, or should, be simply a record of successes.

I do not doubt that engineering is an exact science, but engineers have never found out the exact way to apply this science to the ever-shifting conditions under which they must do their work. An engineer's most careful and exactly figured-out designs sometimes surprise him more than other designs under quite as difficult conditions to which he had given little time or thought.

The static laws and dynamic forces in his most carefully planned machines get into most fatal misunderstandings with one another, and he stands puzzled amid the mechanical wreck, without any satisfactory reason furnished by the result to show why this thing, that figured out exactly right, should be so hopelessly wrong. But if he be wise, the impression will not be lost, and will always appear as a bright mental picture whenever his opinion is required on a class of mechanism of which this picture is a type.

Did you ever observe the difference in the appearance of a piece of mechanism that had been designed on scientific principles, with every part figured out to stand the strains that theoretically should come upon them; every journal having just the proper amount of surface

for the load; and another piece of mechanism for the same duty, but which had been developed by experience with the working of many predecessors? No scientific reason could be given for the forms into which certain parts had developed, except that they would not work satisfactorily in any other form.

A vessel was built on the Atlantic coast several years ago and was engined by a scientific man. Every part was evidently planned in accordance with correct principles, so far as that particular part was concerned. The engine was triple expansion; the forward part of the shaft was made the correct size for the high-pressure cylinder; the middle part was made the correct size for the intermediate pressure cylinder, with the high-pressure added, while the after part was made the correct size for the low-pressure cylinder, with the intermediate and high-pressure added.

I had a talk with the designer of this strange-looking machine, and he was positive that the general practice of marine engine builders was all wrong in this particular, and on many other points.

But there are particular experiences that men acquire and that have a great effect in shaping their practice. For instance, in designing, say, a pump for high pressures, and large quantities, I might, under certain conditions of working, and with certain kinds of water, employ hard rubber valves in metal cases; while under other conditions of working and kind of water to be handled, I would prefer metal valves.

Yet I could not say in advance just what conditions would determine me to choose either way; for while the conditions might not be such as to give a promise of very great advantage to either the one kind or the other, something else, as for instance, what kind of valve could be most readily procured in the place where the pump was to be operated, might decide the question for me.

I have said something about engineering being an exact science; this is true only in part. The laws that govern bodies in motion and at rest, the expansion of gases, the conservation of heat and energy, are all exact in their operation, and the same conditions will always produce the same results. But the engineer has to apply these laws and forces through materials in the structures and in the machines which he designs, which are ever varying in their qualities of strength and endurance, and which may behave satisfactorily at one time and fail utterly at another, when, to all appearances, the conditions are the same.

"Why," he asked, "should the crank-shaft be made of the same size throughout, when, if the engine is properly designed, the forward part transmits but one-third the work, the middle part two-thirds, and the after part the whole work of the engine?"

Here the want of experience resulted in a failure, because the designer thought that the general practice was the result of lack of knowledge. He could not foresee that his journals and crank pins, being all of different diameters and lengths, and consequently having different velocities, would wear unequally, and that the shaft could not be kept in line.

Two metal surfaces may work together, as a journal and bearing, with perfect results at one time, leading you to believe that you had reached the desired end of your search for a satisfactory bearing; yet, when you duplicate it under apparently the same conditions, you can get nothing but disappointment, showing that your first work was very near failure, though you did not know it. This is why some experienced engineers never repeat what was thought by those not in their confidence to be a great success.

Recently there were launched at the Union Iron Works, at San Francisco, two vessels from two sets of ways, parallel to each other. Now, two parallel lines are supposed to stretch out indefinitely, but never to come together. Why did these two ships, launched on parallel lines, come together so suddenly, when their rudders were set to make them diverge? We have not yet been able to find a reason for it.

Our experience is now against launch-

ing two ships at the same time from parallel ways; our experience forbids it being done in that way. Still, some one else might do such a thing and be successful, and thus acquire an experience totally different from ours, and never know how near he came to doing an unsafe thing.

This illustrates what I mean by saying that no man can impart his experience to another, as it is acquired for his own use solely. If we were to be guided by another's experience, progress would be at an end in certain directions.

Men have found that certain things could not be done, because they tried and failed; other men, searching for experience for themselves, will try to do these same things and do them successfully, and thus gather an experience that contradicts that of the others. And this process goes on continually.

What my experience tells me will fail, another's experience tells him will succeed, and yet my own experience must guide me, and not that of another. Experience is a thing of slow growth, for often the first impressions produced by our work have to be modified as certain tendencies on the part of the work develop.

This is especially true of moving mechanism. An engine or machine may make a fine start, and engineering experts may give good reports of it, so that its designer may feel justly proud of the result of his labours. But by and by certain tendencies begin to manifest themselves; workmen are employed nearly every night on it to keep it in condition to run in working hours; still the fatal tendencies keep developing until the machine is broken in constitution and must be abandoned.

This is the end of many a fair start, and alas, how many of the model engines and machines that get conspicuous illustration and description in engineering publications come to just such an end! On the other hand, machines that required careful nursing at the start have developed constitutional strength that enabled them to serve their day and generation with credit.

I have found it very instructive to go back ten or twenty years and study the designs for engines and machinery that figured in the engineering papers and magazines, and were advertised at the time as the results of the best experience of the firms making them, and trace them on through the succeeding years.

Very many of those receiving the highest commendation drop out of existence altogether, experience having shown them to be constitutionally defective; while others, having sound constitutions as a foundation of development, appear again and again, modified to suit varied conditions, but still showing through all changes the good stock from which they sprang.

About twenty years ago I was entrusted with designing the hydraulic elevators and other work for the Palace Hotel, then building in San Francisco. Something was desired far in advance of anything that had been done in the elevator line, both in speed and power, and I had full power to make what I thought would best meet the requirements. I decided on hydraulic elevators, therefore, using water at 700 pounds pressure per square inch.

The designs were very elaborate and introduced many new features that have since become permanent factors in that class of work.

I had had some experience in hydraulics and knew that that class of work had to be carefully nursed at the start; I will never forget the nights I had to sit up with the hydraulic machinery in this particular case.

Sir William G. Armstrong, who had done so much in Great Britain in hydraulics, visited San Francsco when I was nursing my hydraulic child, and I took him all over the work. At the time I was feeling a little discouraged, but he buoyed up my hopes by remarking that hydraulic machinery needed a lot of care at the start, but, if well designed, was likely to last long and give good service. "Your main parts are all right," he said, "and you will soon be out of all trouble with it."

This proved true, for to-day those

particular hydraulic elevators are still doing good service, and have kept their own against even the electric novelties in the elevator line.

Failures in details that are corrected, enabling the main features of a design to remain as designed, are perhaps the best teachers of experience. Where a design fails utterly it is hard to get any helpful experience from it, as in some cases a total failure may result from a small detail being wrong. An experience of this kind sometimes may retard progress and raise a prejudice that we may mistake for experience.

About twenty years ago I began a study of enclosed engines for high speed, and thought I could construct such an engine, all lubrication being done by the steam. I took the opportunity that presented itself in having to furnish a circulating pump in connection with a surface condenser fitted to the engines of the steamship *Prince Alfred*, then running to Victoria, B. C. The engine which was designed was cheaply constructed and ran at 300 revolutions per minute without noise or jar, so that I considered the problem solved. It gave no trouble whatever during a trial trip, and was accepted as a great success.

The vessel took in cargo and passengers and started on her voyage with everything working well, but just after she crossed the bar the condenser suddenly got hot, and the engineer noticed that the centrifugal pump had stopped, although it appeared to be all right on the outside. So, turning on the sea injection, as surface condensers were then so fitted, he returned to port and sent for the designer of the engine that had so suddenly stopped work. On opening the machine nothing was found inside but a few shapeless pieces of metal; it had gone to pieces internally, leaving no clue as to what part had caused the wreck. There was nothing to do but buy an engine that would run the pump and let the vessel go to sea.

Here was an experience that taught nothing, but created a prejudice in my mind against enclosed engines as a class. Such engines are now made in large numb rs, and for cεrtain purposes are very satisfactory.

A single incident, such as this, should never be allowed to stand for experience; our experiences must be the result of wider observation than the limited horizon of our own work. We must make careful studies of other men's work; we cannot get their experience with their work, but we can test our observations of what others do by our experience of what we have done in the same line ourselves, and thus enrich and broaden our ideas of the possibilities within the branch of engineering in which we have chosen to labour.

WOODLANDS, BLACKHEATH, MR. YARROW'S RESIDENCE.

ALFRED FERNANDEZ YARROW,

A Biographical Sketch.

AMONG the pioneers in the designing and building of vessels of exceptionally shallow draft, capable of attaining speeds which, only a few years ago, were considered as far beyond the limits of possibility, Alfred F. Yarrow stands out pre-eminently.

His father was confidential clerk to the London firm of Stiebel Brothers, a commercial house of high standing, having extensive business relations with South America. He was a man of an exceptionally kind and amiable disposition, and consequently had an excellent influence over his family. He died at the time his son was about launching out into business life. At first this loss seemed irreparable, but possibly it was for young Yarrow's ultimate good, as it threw him all the earlier entirely on his own resources.

His early school life was spent with Mr. Sonnenschein, the well-known teacher, and finally at the University College School, London. Through the influence of a relative, soon after the age of sixteen, he was apprenticed to Messrs. Ravenhill & Co., London, who in those days occupied one of the first positions as marine engineers in Great Britain. He passed through the

YARROW AND HILDITCH'S STEAM PLOUGH.

various shops, then into the drawing office, and at the age of twenty-one he left.

Both before and during his school days he was continually associated with his friend, Mr. James B. Hilditch, who had strong mechanical tastes, resulting in their entering jointly into numerous enterprises and always working together in the workshop in the evening. At the age of about seventeen these young men made telegraph instruments for themselves and connected their respective houses, which were about half a mile apart, by means of an over-house wire; as a matter of fact, this was the first over-house telegraph in London, although a few months later one was inaugurated by Sir Sydney Waterlow between his two places of business.

THE MOVABLE ANCHORAGE.

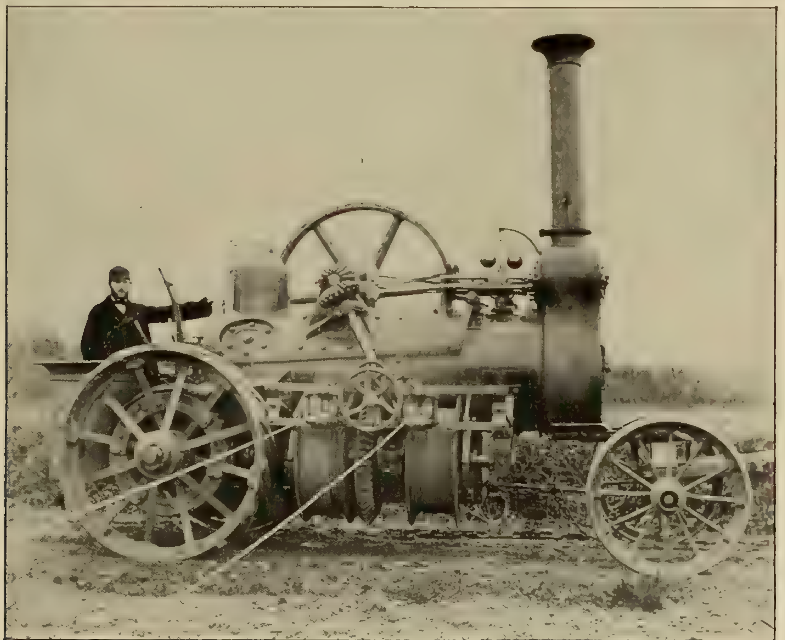
In days when there is so much agitation for shortening the hours of labour it is interesting to record that both young men were to be found working sometimes both before as well as after the usual hours of daily occupation in pursuit of their favourite hobbies. Their lathes often were not stopped till long after their respective families had retired to rest. Whilst every available moment was snatched for the purpose, Saturday afternoons and holidays were eagerly looked forward to as special opportunities for experimenting with steam, electric, photographic, or scien-

tific apparatus of some kind, and both now acknowledge this to have been a very happy period of life to look back upon.

When between twenty and twenty-one years of age Yarrow and Hilditch took out several patents for improvements in steam ploughing apparatus, which was then coming to the front. It was customary in the Fowler plan, which was the leading one at the time, to place an engine on one side of a field, with a powerful movable anchorage at the other, and to work between the two a double-acting balanced plough, which, by means of a steel wire rope, would first be drawn towards the engine, ploughing with one set of ploughshares; then, on arriving at the engine, it was hauled back by a wire rope which passed around the anchorage, the plough itself being balanced over so that the other group of ploughshares came in operation.

With this system the movable anchorage on the side of the field opposite to the engine had to stand double the strain that was necessary in order to haul the plough. This anchorage consisted of a large pulley around which the wire rope passed. The pulley worked within a frame supported by strong disc wheels which buried themselves in the ground as the frame moved slowly along, and thus secured side resistance.

It happened, however, that in many cases the resistance so obtained was not sufficient, and the anchorage was overturned, sometimes resulting in an accident. To avoid this, Yarrow and Hilditch devised a scheme by which this powerful anchorage could be dispensed with. Two single-acting ploughs or cultivators were adopted, in lieu of one double-acting one, the one plough being drawn from the centre of the field towards the engine and the other being drawn from the anchorage to the centre of the field, only one of these ploughs being in action when drawn towards the engine whilst the other was running back light. It will thus be seen that the anchorage on the side of the field



THE ENGINE OUTFIT FOR YARROW & HILDITCH'S STEAM PLOUGH.

YARROW'S STEAM CARRIAGE OF 1864.

opposite to the engine was required to have only sufficient resistance to draw the empty ploughs back to take up a position from which they could start forward again.

The Yarrow and Hilditch system received considerable support by some of the leading agricultural engineers. Twenty-four sets alone were sold to the Khedive of Egypt to develop cotton cultivation on the banks of the Nile. This brought Mr. Yarrow into contact with several of the best firms in England and may be considered as the starting point of his ultimate success.

About the same time Messrs. Yarrow and Hilditch took out a patent for some improvements in steam carriages for common roads. Several of these were built and they attained a moderate amount of success. Owing, however, to the obstruction which they met with from legal enactments prohibiting the use of steam carriages on the highways, the matter was ultimately dropped. At this point in their lives the two men drifted apart, so far as regards business, owing to Mr. Hilditch being called upon to join his brother in carrying on their late father's business in the silk trade; but the affection between them has ripened with years, and it is no uncommon sight at the present day to see them chatting together in the Yarrow works.

Soon after the age of twenty-one Mr. Yarrow was appointed London representative to Messrs. Coleman & Sons, engineers of Chelmsford, with a view to the sale of their steam ploughs. This arrangement was continued for two years, shortly after the expiration of which Mr. Yarrow started a small factory, in conjunction with Mr. Hedley, on the Isle of Dogs, Poplar, under the name of Yarrow & Hedley. The first important contract which they undertook was the construction of some powerful pumping machinery for the dock owned by Messrs. Wilson, Sons & Co., in Rio de Janeiro. Later on their attention was attracted to what was deemed by them a new direction for engineering enterprise, namely, the construction of steam launches.

As an interesting anecdote of the

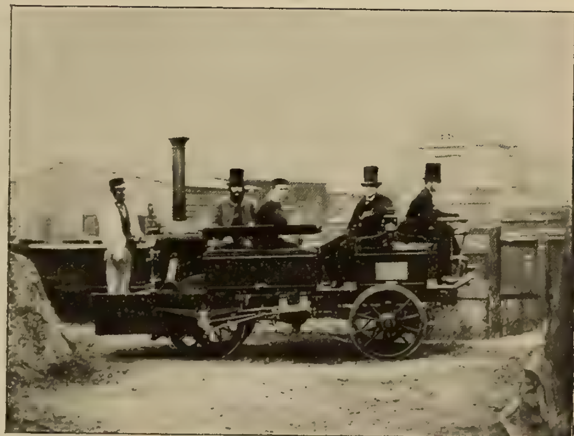
difficulties that are met with by inexperienced young men on first starting in business, the following will serve as an illustration:—One of the first orders which the firm of Yarrow & Hedley secured was to repair certain machinery for a well-known firm of makers of pickles and jams. The work was carried out and the invoice sent in. Repeated calls for payment resulted only in promises for the future.

Mr. Yarrow, ascertaining that the firm was in a very unstable financial condition and that in all probability the amount of the invoice would never be paid if he took no further steps in the matter, arranged for a very large order for soap, candles, jams, pickles, etc., to be sent to the firm, with a view to cover an amount equal to the invoice for the engineering work executed. The quantity of household requisites was so extensive that Mr. Yarrow had to resell them among his friends, and the supply of soap and candles lasted some ten or twelve years.

The business connection between Messrs. Yarrow & Hedley continued for nearly ten years, when they separated. The latter days of their partnership were not quite as serene as could have been desired, but this did not prevent Mr. Yarrow, to use his own words, from "doing what most young men do," for within a few weeks of the dissolution of one partnership he entered into another of a still more binding character by marrying a Miss Franklin, who, during the course of their married life, has presented him first with three daughters and then with an equal number of sons. It is doubtless a source of great pleasure to Mr. Yarrow to know that the firm he has founded will not, in the second generation languish for a leader, who, it is hoped, will prove himself to be a worthy son of the distinguished founder.

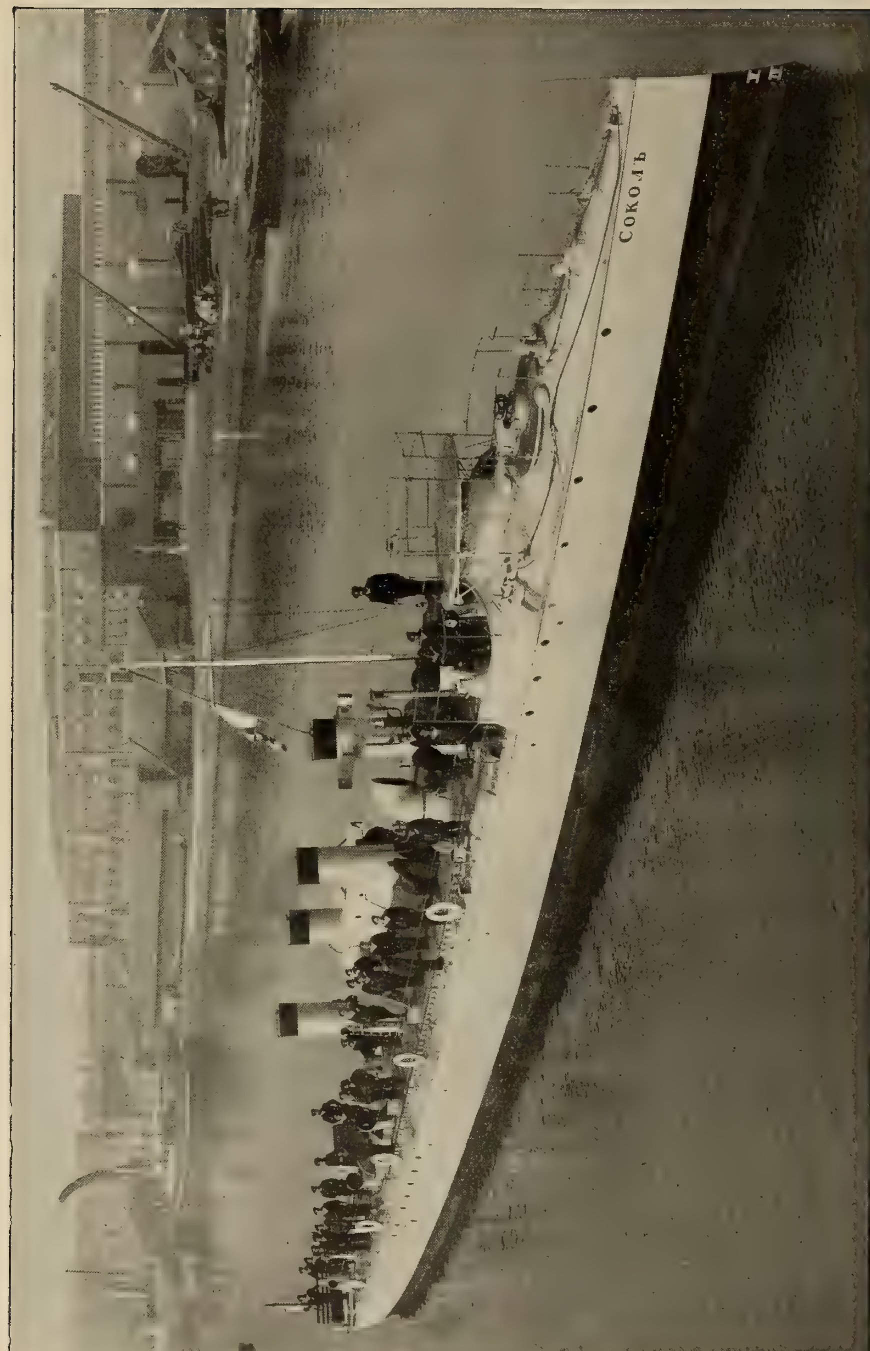
From the time Hedley and Yarrow parted company the business has been carried on by the latter, alone, and its success has been by leaps and bounds. Up to the present the firm has constructed 1050 steam vessels of every shape and form, probably exceeding in number the record of any other contractor.

Among them may be mentioned the *Ilala*, constructed for the Livingston expedition, and named after the place where Dr. Livingston died. This was a little vessel of which every part was bolted together, and not rivetted, the object being to ascend the Zambesi and Shire rivers and eventually to get on Lake Nyassa, steaming such parts of the way as the draught of water allowed and then taking the vessel to pieces at intervals where shallows or cataracts were met with. Under the direction of Capt. Young she was successfully placed on Lake Nyassa and has done good service there for very many years. Another interesting vessel was *Le Stanley*, built for His Majesty, the King of the Belgians, for the Stanley Expedition.



YARROW AND HILDITCH'S STEAM CARRIAGE.

This craft was built on the stern-wheel principle, the hull being subdivided into a number of floatable sections, each of which was furnished with four wheels, so that the hull could be readily put together or taken to pieces, when together being a steamer and when taken to pieces and the wheels attached, form-



THE RUSSIAN TORPEDO BOAT DESTROYER "SOKOL," AS SHE APPEARED WHEN ON THE POINT OF LEAVING ENGLAND FOR RUSSIA.
BUILT BY MESSRS. YARROW & CO., LTD., LONDON.

ing, as it were, eight trucks. She was hauled overland round the Falls of the Congo and navigated the Upper Reaches with success for many years and is still doing good service.

During 1886, while the Nile Expedition, under Lord Wolseley, was being prepared, Sir Cooper Key, then a leading spirit at the British Admiralty, selected Mr. Yarrow to assist Lord Wolseley in designing the most suitable class of vessel for the expedition which was considered imminent, but owing to the continual delays in coming to a decision on the part of the government, time was allowed to slip by, and the rowing boat scheme had to be adopted. However, several stern-wheel steamers were built by Messrs. Yarrow & Co., and those which were sent out to the Nile proved eminently successful, and in the expedition of last year some of these steamers (ten years old) took the leading part.

The firm constructed the *Mosquito* and *Herald* for the Zambesi Expedition in the year 1890. These were vessels on the same plan as *Le Stanley*. In 1892 the *Opale* was built for the French Government, for service in Dahomey. This was deemed so great a success that a number of these vessels, almost exact copies, were constructed in France, both for West Africa as well as for the Madagascar Expedition. This system of construction, introduced by Messrs. Yarrow & Co., has been extensively adopted, as it meets a want for vessels too large to ship whole and too weak to navigate across the ocean.

A very large part of the work carried out at Poplar has been the construction of torpedo boats. In recent years the British Admiralty determined to construct a number of very fast boats of this kind, having a higher speed and greater sea-going qualities than any built up to that time, and with a view to the successful carrying-out of their wishes, the Poplar firm was consulted, resulting in the construction of the *Havock* and the *Hornet*, which were the first two vessels of this type built, and were termed by the British authorities "torpedo boat destroyers", although they are practically torpedo boats of a somewhat larger size than those formerly built. It will be remembered that these boats displayed their qualities at Portsmouth before a number of the

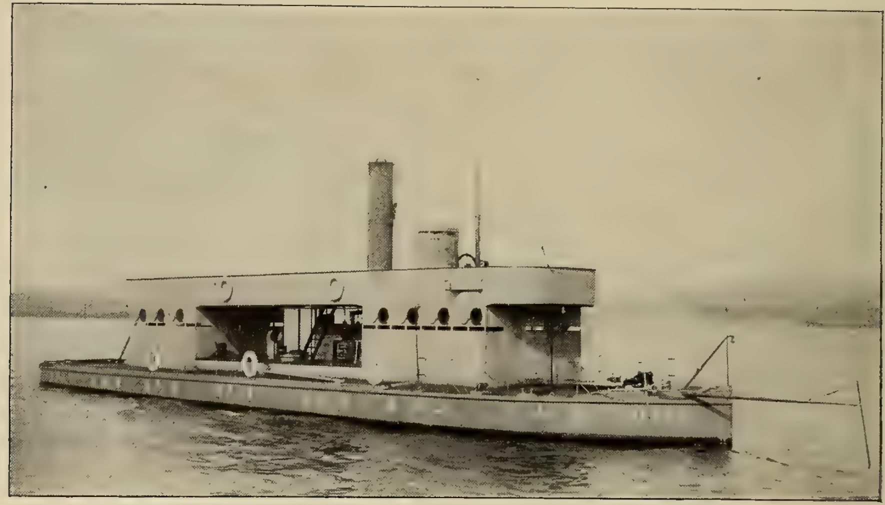
A YARROW SHALLOW DRAFT GUNBOAT, BUILT UP OF FLOATABLE SECTIONS, FOR READY TRANSPORT.

Members of both Houses of Parliament, and their success ultimately led to the Admiralty increasing this arm of the navy to a very large extent. The speeds obtained with the *Havock* and the *Hornet* were 26 and 27½ knots, the difference in speed being due to the fact that in the *Havock* locomotive boilers were adopted while in the *Hornet* the Yarrow water-tube boiler was used.

Among this class of vessel may be specially mentioned the *Sokol*, built by Messrs. Yarrow & Co. for the Russian Government. With this boat a speed of 30 knots was secured. The *Sokol* turned out to be so satisfactory that the Russian Government at the present moment are building a large number of exact copies in their own yards.

The development of the water-tube boiler cannot be referred to without mentioning the work done by the Poplar firm. The Yarrow boiler differs from all others of the small-tube type in having the tubes perfectly straight, so that they can be easily examined and cleaned. They are cheap to construct, and recent experiments have shown that in point of economy they stand second to none. The adoption of the Yarrow boiler has been very rapid, it having been introduced in nearly every country possessing a navy. Interesting experiments carried out by the firm, so as to throw light on the principles which govern the circulation of water in water-tube boilers, were made public in the beginning of last year, and have added largely to the information of the engineering profession on the subject.

Recently Messrs. Yarrow & Co. have constructed eight shallow-draft twin-screw steamers, some for the Egyptian Government and some for the British Admiralty. These vessels are for fighting purposes. The results have considerably exceeded the conditions of the contract. In the smaller vessels, which were 100 feet in length and 20 feet beam, the draft was found to be under 2 feet when carrying a load of 25 tons, and the speed, 10½ miles an hour.

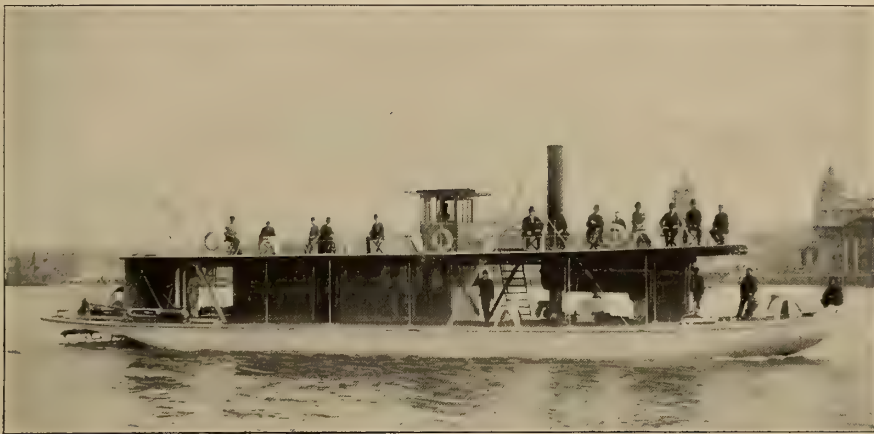


A SHALLOW-DRAFT GUNBOAT. BUILT BY MESSRS. YARROW & CO., LTD. LENGTH, 100 FEET; BEAM, 20 FEET; DRAFT, CARRYING 25 TONS, 23 INCHES; SPEED, 10½ MILES AN HOUR.

The Nile steamers were of larger size, 145 feet in length by 24 feet 6 inches beam; draft, 2 feet when carrying a load of 35 tons; speed, 13 miles an hour during a continuous run of 2 hours.

These vessels are provided with propellers which are considerably larger in diameter than the draft of the vessel. They do not work below the bottom of the boat and still they are fully immersed, due to the peculiar formation of the hull. Important features in these gun-

boats for fighting purposes are that they are under perfect control and have good manœuvring power, both going ahead and going astern. They are built in sections of such dimensions that they can be transported to any part of the world, and as each section is floatable, the entire structure can be united while in the water, thereby avoiding the delay and difficulties incidental to rivetting up and launching in the usual manner.



A YARROW GUNBOAT FOR AFRICAN SERVICE. BUILT COMPLETE IN 25 WORKING DAYS.

A SHALLOW-DRAFT FRENCH GUNBOAT, BUILT BY MESSRS. YARROW & CO., LTD. WORK WAS COMMENCED ON APRIL 28 AND THE BOAT WAS FINISHED ON MAY 23.

Mr. Yarrow is a member of several scientific societies, but the only one in which he takes an active part is the Institution of Naval Architects, before which body he has read a number of valuable papers relating to naval architecture and marine machinery.

He also delivered a lecture before the Royal United Service Institution in 1884, and as far back as the year 1862 he read a paper on "Steam Carriages" before the Society of Engineers. It may also be mentioned that the Civil and Mechanical Engineers' Society, whose meetings from time to time are recorded in the technical press, was started by the apprentices at Messrs. Ravenhill's, in which Mr. Yarrow took a very active part. He was for many

years vice-president. During his extensive business career, Mr. Yarrow has enjoyed the patronage of every important naval power. Missionary societies, too, who seek to spread the "glad tidings" with the assistance of a modern steamer, have called upon his resources. There is scarcely a South American river which is not traversed by a Yarrow shallow draft steamer. From the Magdelena to the Straits of Magellan may be found passenger and stern-wheel steamers, dainty yachts, swift revenue launches, torpedo boats, and destroyers, the product of the Yarrow Works.

Although the work at Poplar is, and always has been, a specialty, Mr. Yarrow has never been averse to giving assistance to the large number of foreigners who visit British shores annually, "in search of some new thing," or to add to their store of information. Accredited representatives of foreign powers and private yards are always sure of a warm welcome, and it is no unusual thing to see the attachés of past and possibly future foes fraternising in the Yarrow arsenal.

One interesting feature in connection with the Poplar yard is that it was on this very spot that Peter the Great, when he came to London to learn shipbuilding, passed a portion of his working days. Adjoining the yard when it was first started was a public-house called the "Folly", mentioned in Macaulay's "History of England" as a frequent resort of King Charles. It was, in olden times, one of the many centres of smuggling on the Thames, and some 15 years ago old inhabitants in this neighbourhood could remember the time when the gibbets upon which smugglers were hanged still remained on Blackwall Point, opposite the "Folly".

Allied to Mr. Yarrow, who devotes much of his time to experimental work and to new designs, is a staff of highly trained gentlemen, on whose energy, perseverance, and devotion the successful carrying on of the business so much depends, and their chief, both in public and private, is untiring in his praise ot those with whom he is associated, acknowledging with pleasure the value he attaches to their co-operation. Mr. Yarrow has the natural gift of making friends, and when once a friendship has sprung up between him and others, he has never been known to lose such, or forfeit their confidence and esteem.

But to know Mr. Yarrow thoroughly, and to appreciate him, it is not only to Poplar that one must go, nor to his home at Blackheath, but away from London's roar to the green lanes and fields of Kent, where, in the neighbourhood of Broadstairs (endeared to memory by Dickens, who wrote to alleviate the bitter cry of outcast London), Mr. Yarrow, with an aim and purpose as noble as that of the novelist, has erected and endowed a Convalescent Home for Children, irrespective of nationality or creed. One must visit Broadstairs to rightly learn to what purpose the successful engineer has devoted his fortune in his lifetime. In the founder's own inimitable way, the Home circulars are endorsed, "No subscriptions are solicited, neither will they be accepted." This, in a few words, illustrates the character of its founder.

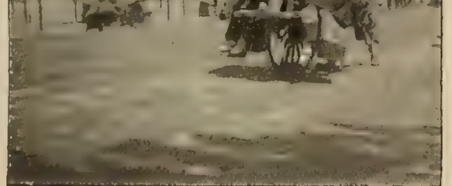
Moreover, while to some, Mr. Yarrow is only looked upon as a great engineer and shipbuilder, to a large circle he is known as a kind host, and his hospitality is proverbial; in fact, both Mr. and Mrs. Yarrow are well known for their genial qualities, and when receiving guests at their not by any means small, yet modest home,—Woodlands,—the most nervous stranger need have no occasion for uneasiness, if he be fortunate enough to secure a seat by the side of either Mr. or Mrs. Yarrow.

Woodlands, Blackheath, is of historic interest, inasmuch as it was erected about the year 1770 and at that time commanded a beautiful view of the valley of the Thames and the opposite coast of Essex. It was here that Mr. John Angetstein lived, and on his death his splendid collection of pictures formed the nucleus of the present National Gallery.

Current Topics.

The effect of oil on troubled waters has become almost proverbial, but probably few have ever given more than passing thought to the remarkable nature of the effect considering the immeasurable thinness of the oil covering. A film $\frac{1}{80}$-millionth of an inch thick produces marked results, and yet, according to Sir Benjamin Baker, to cover the whole 135 acres of painted surface of the Forth Bridge with a coat of that thickness, would require less than a pint of oil. It would appear inconceivable that such a membrane could in any way affect the ocean in a storm, and yet all available experience tends to show that the small quantities of oil which have been applied, with good results, in heavy seaways, could not have given any but the most minute thicknesses of coating.

One of the chief means of travel and transport in China, especially in the northern part of the empire, and throughout the Great Plain, is the wheelbarrow, — not the wheelbarrow such as we know it, but, in point of fact, a decided improvement on the types used in Western countries, for it is so constructed that the load, which sometimes is very great in bulk and weight, is carried over the wheel, and not between it and the man who propels it. Through the courtesy of Mr. Charles Mayne, of Shanghai, we are enabled to reproduce on this page a



A CHINESE WHEELBARROW.

photograph which fairly portrays the peculiarities of the vehicle. To aid in steadying and propelling it, as explained by Mr. Mayne in a note recently contributed to the British Institution of Civil Engineers, the wheelbarrow-man

wears across his shoulders a strap which is attached to the shafts on each side. Boxes, bales of goods, or whatever the load may consist of, are secured to the wheelbarrow by ropes, and the charge for carrying an average load is about 1s., 5d. per mile, varying according to the load and the state of the road to be travelled over. There are seating accommodations for four people, two on each side, and the fare for four people is 2¼d. per mile, being lower than that for merchandise on account of the avoidance of labour in loading and unloading. A cushioned seat is provided for the passenger, who generally sits with one leg resting on the front of the barrow and the other hanging over the side in a rope loop which serves as a foot rest. On the Great Plain, wheelbarrows are occasionally seen with a sail set, when a fair wind proves to be a great help to the trundling of the barrow over a level way.

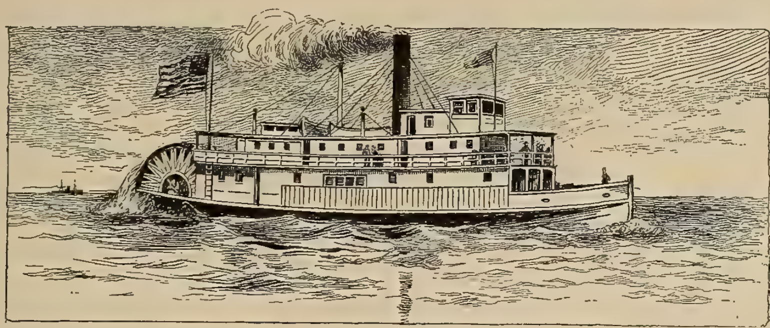
SINCE the institution of cotton mills at Shanghai, the wheelbarrow has been extensively used as a passenger vehicle, especially for carrying work-women to and from the mills. One man can wheel six women for a distance of about three miles, morning and evening, the charge being 1s. 5d. per month. The average earnings of a wheelbarrow-man are about 8½d. per day. About 4000 licenses are issued monthly to the same number of wheelbarrows plying for hire in the streets of the foreign settlements at Shanghai, where, being under the municipal regulations, they are perhaps the best in China. Sometimes as many as fifty barrows may be seen in the streets, travelling one behind the other, each carrying two barrels of English Portland cement and pushed by one man. Very frequently a load is carried on one side of the barrow only, and it is extraordinary to see a Chinaman skilfully balancing and propelling it. The upsets and accidents, too, are remarkably few when it is considered that about 4000 of these vehicles are in use in the streets in addition to a large traffic of other kinds.

AN interesting contribution to the once much-mooted question of screw *versus* paddle efficiency is afforded by the little illustration on this page, representing two of the earlier steam vessels of the British Navy, the paddle steamer *Basilisk* and the screw steamer *Niger*, towing stern to stern, the vessels exerting their utmost power in opposite directions. From the very meagre particulars which are available it appears that this trial of power took place in the English Channel on June 20, 1849, and lasted one hour, in which time the *Niger* towed the *Basilisk* at the rate, by patent log, of 1.466 knots per hour. Both ships were of very

A SCREW *VS.* PADDLE TEST IN 1849.

nearly the same dimensions, the former having a length of 194 feet, and beam of 34 feet, while the latter measured 190 feet and 34 feet, respectively. The tonnages were 1073 and 1030, and the horse-power equipments, 406 and 400, respectively. Both ships, too, were constructed at the Woolwich Royal Dock Yard, and the conditions, therefore, were as nearly alike as one could well wish them to be for the purpose of a fair comparison.

In only rare instances is a river steamboat expected to undertake an ocean voyage. For even a staunchly-built, small vessel a trip of this kind is fraught with unpleasant possibilities, and when a boat has all the pronounced shallow-draft characteristics found in Western American river practice, the outcome of such an undertaking becomes still more problematical. It is worth noting, therefore, that during the early summer of this year an American Pacific coast-wise voyage of over a thousand miles was successfully completed by a craft of this kind. During the past season there had been an extraordinary demand on San Francisco bay for flat-bottomed river steamers and a number of San Francisco business men, therefore, conceived the idea of bringing down an idle steamer from the Columbia river up the coast, succeeding after some delay in starting the boat *H. C. Grady* on the long voyage. To seafaring and insurance men it looked like tempting Providence, and the crew which had been sent up to bring the steamer down, deserted. As a last resort a motley crew of landlubbers was shipped, and, with Captain Denny, her commander, reaped the credit for the safe arrival of the vessel at San Francisco. The *Grady*, as a glance will



THE "H. C. GRADY," ON A THOUSAND-MILE OCEAN VOYAGE.

show, is built on somewhat different lines from those of an ocean-going craft, and ought to be considerably more at home in a river full of sand bars than in the storms of the misnamed Pacific. The guards are scarcely three feet out of water, and the flat bottom is somewhat less under water. On top of this are the cabins and pilot house, reaching high in the air, and offering a fine broadside to any stray squalls. The unwieldy stern wheel also assists to make bad matters worse, as every time the bow dips the stern flies up, throwing an added strain on the engines. After five days of tossing and twisting, the Golden Gate was reached, and on the following morning the steamer was safely moored at one of the city's wharves, where she was the object of much interest to those who had prophesied that she would never reach port. The boat is only 125 feet long, with 26 feet beam, and 26 inches draft.

The question of economical power transmission by means of compressed air is largely one of size of pipe, and where long distances are to be traversed this becomes a guiding factor. Mr.

William L. Saunders stated a short time ago before the New York Railroad Club that to carry compressed air power from Niagara Falls to Buffalo, say, 250,000 H. P., a pipe forty feet in diameter would be necessary, and this, of course, would be too large to be a commercial success. The only alternative in such a case would be to subdivide the power into horse-powers of about 50,000 and these would each require a pipe about four or five feet in diameter. For ordinary cases of compressed air transmission, however, the size of pipe necessary is quite small. Mr. Saunders cited the case of a certain railroad signaling system for which a 2½-inch line, about 8 inches long, had been laid, to supply the air necessary for operating the signals, and this has been in successful operation for a number of years. In the United States, in Michigan, the power obtained from the falls of the Menominee river is used to compress air, and this is transmitted to the Chapin Mines, 3 miles off, through a 24-inch pipe, with a loss of pressure in that distance of only two pounds.

Sir Nathaniel Barnaby, at one time chief constructor of the British Navy, was consulted several years ago by a business man, well known on both sides of the Atlantic, as to the possibility of building a steel ship which would not roll, or pitch, or heave in the sea, and in which, therefore, the bulk of passengers would be in less desperate hurry to get ashore. A vessel of this kind appeared to Sir Barnaby to be perfectly practicable with a draft of water of 26 feet. The minimum length and breadth, he thought, ought to be 1000 feet and 30 feet, respectively, and it was estimated that with engines of 60,000 horse-power an ocean speed of 15 knots could be obtained. Two sets of apparent difficulties had to be overcome, namely, those connected with the building of the ship afloat, and those relating to receiving and discharging cargo. The building difficulties soon disappeared, and to meet the others it was proposed to form shallow, still-water harbours, or docks, within the ship, to be entered through gates in the sides, and to carry, always afloat there, barges and tugs for transferring the cargo from ship to dock and vice versa. A vessel, built on this general plan, could, it was thought, be made absolutely secure against fatal injury arising from perforation, and the subdivisions required for this purpose might, moreover, be made to serve effectually against the spread of fire. The ship was not built, but something like it may yet become one of the interesting experiments of the future.

The days of the catalogue as a sales agent in the engineering export trades appear to be numbered. Experience has shown that even though the catalogue or price list be printed in the language of the country where the business is to be found, and even though it be circulated liberally, something more is necessary to actually get the business, and that something is personal representation. Men should be sent, and not catalogues, —men who understand the machines and appliances which are to be sold, and particularly the people to whom they are to sell. British and American machinery builders should long ago have kept pace with the enterprising Germans in this respect instead of learning slowly by commercial disappointment that somebody had reaped the harvest ahead of them.

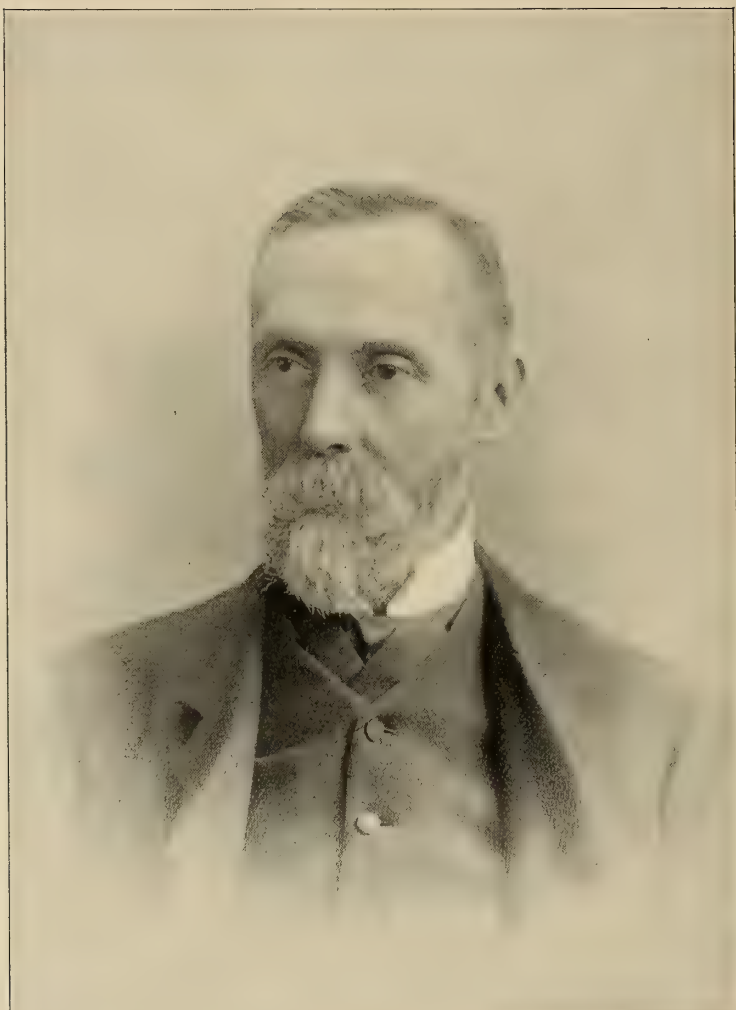


PHOTO. BY WEBSTER & CO., WANSTEAD, ENGLAND.

Jas Holden

LOCOMOTIVE SUPERINTENDENT OF THE GREAT EASTERN RAILWAY, ENGLAND.

(See Page 178.

CASSIER'S MAGAZINE.

VOL. XIII. DECEMBER, 1897. No. 2.

ELECTRIC LIGHT FROM CITY REFUSE.

By Nelson W. Perry, E. M.

PERHAPS there is no stronger evidence of the advance of civilisation than the increasing tendency manifesting itself in almost all directions towards the utilisation of waste products.

The immediate incentive to this, of course, is the simple incentive which lies behind all commercial projects,—the desire for the emoluments of trade; but it is the increasing ability to turn to commercial account those products which before were worse than a mere waste, in that their disposal was a source of expense, that is the index of civilisation's advance just mentioned.

No better example of this can be cited, perhaps, than the utilisation of the waste products in the manufacture of coal gas. Take a single one of these, coal tar, for example, which, by the way, is a very complex and uninviting substance. It has given us one of the best antiseptics known to science in the shape of carbolic acid, one of the most violent explosives used in warfare—picrate of potash; a whole series of colours and dyes, the anilines, rivalling in brilliancy and splendour the colors of the rainbow, and these have not only given rise to new industries of great magnitude, but have revolutionised others of vastly greater extent; many of the most delicious of our so-called fruit flavouring extracts; saccharine, a substance two hundred and thirty times as sweet as the purest cane sugar, and last, but not least, a series of medicinal preparations of the greatest value to suffering humanity, of which antipyrine, antifebrine, and sulphonal are names that will be familiar to all.

While this is not a tithe of the blessings which science has succeeded in wresting from that dirty and ill smelling refuse, coal tar, it may serve, in a way, to indicate how little we can afford to regard anything as useless simply because we have as yet found no way to make use of it, or because it is so ill smelling and obnoxious as to constitute it a nuisance which the authorities require the producer to abate.

Many of these useful products are obtained from the waste only by very complicated and expensive processes, and, therefore, could not come into commercial existence unless they possessed some intrinsic merit justifying the time, skill and expense of their manufacture. This notably is the case with saccharine, which cannot be used as an adulterant of sugars, although it might be so used profitably if it could be man-

THE SHOREDITCH SCAVENGING WHARF AND STABLES.

ufactured at less than 230 times the cost to manufacture sugar.

It is so, too, to a less extent, with antipyrine, antifebrine and sulphonal, but all of these are drugs and would be manufactured for their therapeutic value were the cost many times what it is.

The others mentioned compete with older natural or commercial products, the anilines because there are no other colours so beautiful, and few so cheap; the flavouring extracts, not because they are better than the genuine fruit juices or flower fragrance, but because, without being markedly inferior, they are cheaper, and the picrate of potash and carbolic acid simply because of their intrinsic merits.

But there are many secondary products, and most of them must be of this class, that, in order to come into commercial existence at all, must be manufactured at a cost less than that involved in disposing of them at a distance, or less than that which would be involved in their destruction or innocuous disposition in other ways.

Of the latter class a familiar example is vaseline, so indispensable now as a toilet preparation. This was a waste in the refining of petroleum, and so dirty and ill smelling and in all respects apparently so useless, as to be a nuisance wherever disposed.

It occurred to some one to try the experiment of filtering it through bone charcoal, and both colour and smell disappeared. Thus the simple process of filtering had converted a waste into a valuable commercial product, so general in its applications as to be found to-day, not only in every hospital and physician's office, but in every nursery and on every toilet table.

The rendering of dead animals into fertilisers, glue, etc., the conversion of sewage and garbage, offal, etc., into fertiliser, and the conversion of rancid fats into soaps, are all examples of this class with which the public are familiar. But what would we say were we told that recent developments have made the filth that collects in dark places furnish light for those same dark places, nay, even more, become the source of light by which the poor may the better educate themselves; that the refuse from the households where the most rigid

economies become necessities and the disposal of which costs municipalities thousands annually with no other return than the improved sanitary condition of the district, had been made to contribute to the sanitary condition of the district from which it had been collected by furnishing hot water for baths for men and women, and for laundries where clothes could be cleansed and dried; to light the whole district, including public libraries and reading rooms? It would seem to require the touch of the necromancer's wand to convert the wastes of a city into such manifest blessings, were this not the end of the nineteenth century when surprises have ceased to surprise.

This, however, is what is being done to-day in the City of London, and done, too, if reports be true, at a profit to the Vestry of Shoreditch, and the inauguration of the Shoreditch municipal electric supply and dust destructor works several months ago by Lord Kelvin was one of the striking events of the Queen's Jubilee year.

SHOREDITCH TOWN HALL.

Although the cremation of garbage in what, in Great Britain, are called destructors has been common in that country for more than fifteen years, the object of the cremation was solely that

THE ENGINE HOUSE AND OFFICES.

of getting rid, in a hygienic manner, of this material. It was not until about 1888 that Professor George Forbes proposed that the heat of the combustion of this refuse be utilised for raising steam for electric lighting purposes. This plan he recommended to both the corporation of Edinburgh and to the Vestry of Paddington, but in neither of these cases was the suggestion acted upon.

The first definite information that was received in the United States concerning the fuel value of this material also came from Professor Forbes in a paper read before the National Electric Light Association at St. Louis in 1893. In this he said:—

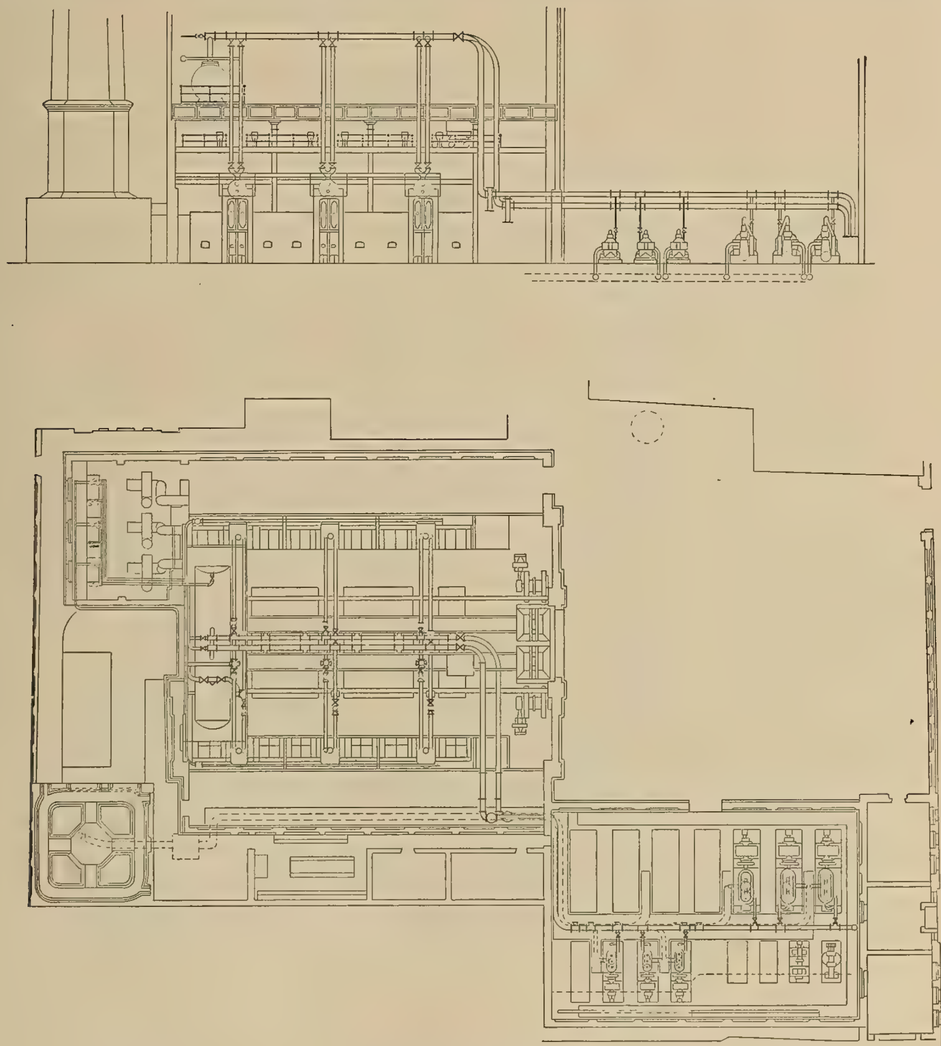
"Taking the ordinary house refuse, consisting of ashes, coal, wood, paper, old boots, vegetables, bones and scraps, crockery, tin cans, iron pots, and bottles, and adding thereto occasionally dead cats and dogs, infected mattresses and condemned meat, I can throw the whole of these, without sorting, upon the furnaces, and, without producing any offensive odour or dust, I can raise the temperature of the gases, where they reach the boilers, to over 2000 degrees Fahrenheit. From my data as to the amount collected in different houses in England per head of population, I find that from the house refuse of any town I can supply enough steam to generate electric light at the rate of one 16-candle power lamp per head of the population for two hours every night of the year. By doing this I am saving the municipality from £2000 to £4000 per annum per 100,000 inhabitants for the cost of removal of house refuse."

These were startling statements indeed, but they are being verified to-day in the Vestry of Shoreditch in the City of London. To accomplish these results, however, it was necessary that the burning of the refuse should be continuous and uniform throughout the twenty-four hours and this involved an efficient method of heat storage, so that the energy generated by the slow combustion of this exceedingly low-grade fuel during the hours of light load might be stored up for use during the few

hours of extraordinary demand largely in excess of the steaming capacity of the plant.

Such a method of storage was found in Mr. Druitt Halpin's "thermal storage," also briefly described by Professor Forbes at the time and later more in detail by the writer at another meeting of the National Electric Light Association. This system consisted in using, in connection with ordinary boilers, large tanks filled, or nearly filled, with water, which, by the continuous operations of the boilers, becomes superheated, thus affording a reservoir of energy which may be drawn upon at will.

Mr. Halpin's original idea was that the boilers and tanks should work under a pressure of 265 pounds per square inch when fully charged, which corresponds to a temperature of 406 degrees Fahrenheit. He proposed that the engines be worked at 130 pounds per square inch, which corresponds to 347 degrees F. The total available heat



ELEVATION AND PLAN OF THE SHOREDITCH MUNICIPAL ELECTRIC SUPPLY AND DUST DESTRUCTOR WORKS.

stored when the reservoirs are fully charged is that due to the difference of the total heat of the water at 406° and at 347° F., or that due to a range of 59 degrees.

Every pound of water falling through that range of temperature will yield 61 thermal units of heat. The total heat required to generate a pound of steam at 130 pounds from water at 347° is 868.8 thermal units; consequently 14¼ pounds of water, falling in temperature from 407° to 347°, will yield one pound of steam.

To allow for radiation loss and imperfect working, 16 pounds of water per pound of steam would be liberal, and placing the steam consumption per effective horse-power at 18 pounds per hour in condensing and 25 pounds per hour in non-condensing engines, we find that the storage room required per effective horse-power hour by this method would be 4.06 cubic feet for condensing, and 6.4 cubic feet for non-condensing engines.

This, it must be admitted, is a very efficient method of storage so far as space efficiency is concerned, and since the storage tanks are merely riveted iron or steel shells, not subjected to the deteriorating influences of fire, it becomes also a very cheap method of storage.

THE DESTRUCTOR HOUSE AND CHIMNEY.

This was the storage plan which it was proposed to use in connection with garbage cremation and which is now being used at Shoreditch.

As to the composition of the so-called ash-bin refuse, there is, of course, considerable variation with locality; but a report on "Dust Destructors" by the medical officer and engineer of the Lon-

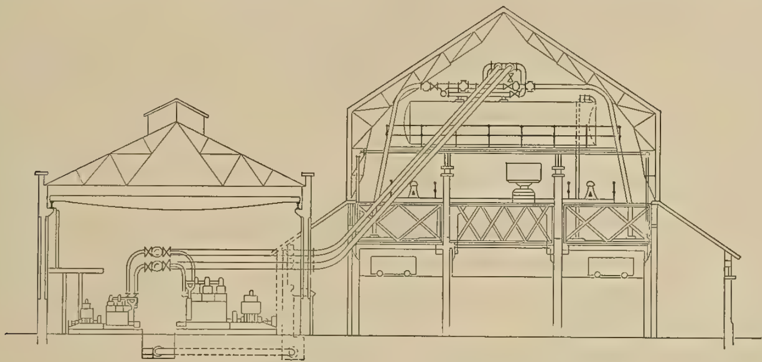
don County Council in 1893 gives the following as an analysis of London "ash bin" refuse:—

Breeze, cinders and ashes	64 per cent.
Fine dust	19 "
Paper, straw and organic matters	12 "
Bottles, bones, tin, crockery, etc	5 "

Professor Unwin gives the fuel value of this refuse at about one-fifth that of an equal weight of fair coal, and, according to C. C. Keep (British Association, 1893), one pound of Birmingham refuse will evaporate 1.79 pounds of water, and at Warrington one pound will evaporate 1.47 pounds of water. According to Watson, experiments at Oldham showed that about 40 pounds of refuse would produce one effective horse-power-hour. Lord Kelvin in a recent interview estimated the fuel value of the refuse at about one-tenth that of good coal. So much for its calorific power.

Carefully compiled statistics show that in Great Britain the quantity of refuse collected varies with the locality from 100 to 400 tons per 100 inhabitants per annum, and this, when burned in destructors, is reduced to about one-third in weight and one-fourth in bulk, the residue after combustion consisting of clinkers and sharp ashes, which have a small salable value for roadmaking and other similar purposes.

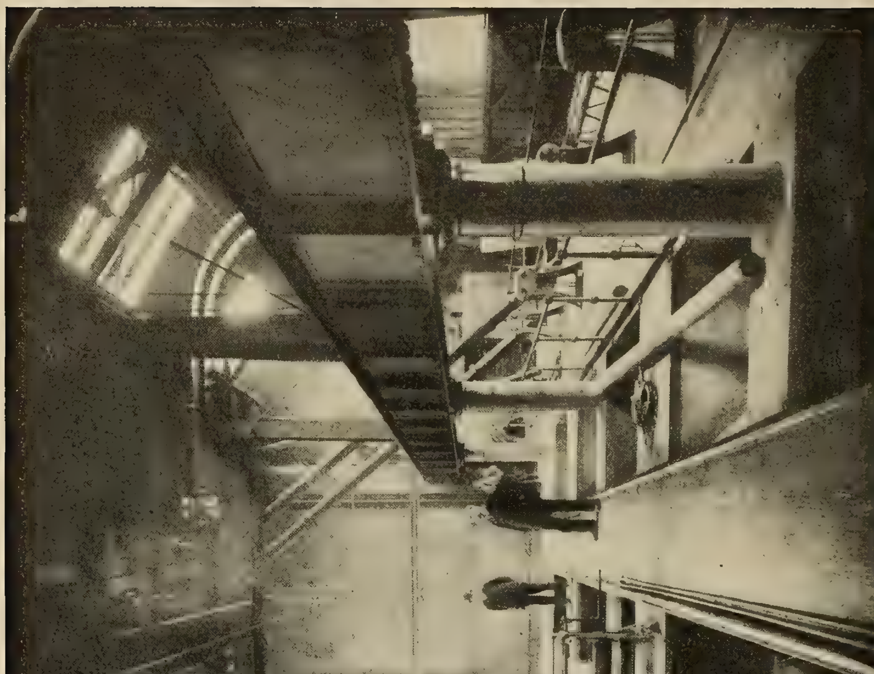
The use of destructors for the treatment of garbage is not new in Great Britain, as previous to the construction of the plant at Shoreditch they had been in use in fifty-five towns in different parts of the country, and in a few instances, as at Southampton, arrangements were made for utilising a part of the waste heat—in this case to raise steam for operating Shone sewage ejectors. But it may be said that previous to the installation at Shoreditch no very intelligent attempt had been made to utilise to its fullest extent the fuel value of garbage. Such, in brief, was the state of the art when the Shoreditch plant was taken up.



CROSS SECTION OF THE ENGINE AND DESTRUCTOR HOUSES.

Shoreditch is a parliamentary borough in the East Central District of London, with an area of about a square mile and a population of 124,000 souls, composed largely of artisans (35 per cent. being artisans, the highest percentage in London). On account of its dense population, the large number of public houses (300) and the number of small shops keeping open late at night, it is one of the largest light consuming districts in London, and, therefore, admirably constituted for an electric lighting district if the light could be furnished at a figure that would be attractive to the class of people living within its bounds.

As far back as 1892 the Vestry obtained a provisional order, and a committee of electrical engineers, consisting of Prof. A. B. W. Kennedy, W. H. Preece, Prof. Ayrton, E. Manville, James M. Shoolbred and S. Dobson, recommended the appointment of Mr. E. Manville as consulting engineer, the plan of burning the house refuse as fuel



ON THE TIPPING PLATFORM.

having already been decided upon. Mr. Manville made an elaborate report recommending the utilisation of the heat generated by the cremation of garbage for the raising of steam for the station and for other purposes.

Later on Messrs. Manlove, Alliott & Co., the chief manufacturers of dust destructors in Great Britain, reported that with the aid of the thermal storage system of Druett Halpin, the burning of 20,000 tons of refuse per annum would produce steam to a value of £4290, and that a saving of at least £1500 would be effected by burning the refuse instead of barging it as heretofore.

As a direct result of this report the Vestry received an offer from certain parties to contract to collect the refuse of the parish at a reduction of about £4000 on the present cost, with a view of burning it for steam generation, but this offer was refused.

From this time on until the spring of 1895 the question of garbage cremation or no-garbage cremation became a political one and candidates for election to the Vestry were compelled to stand on one or the other platform. The cremationists finally won, and Messrs. Kincaid, Waller & Manville were appointed consulting engineers. Bids were received and accepted for the construction of the plant at a cost of £67,646, and on June 28 of this year the station was turned over as essentially completed.

The plant of the Shoreditch Vestry consists of a destructor house and engine house, with offices, pump and fan room and accumulator room. The engine house is 68 feet long by 46 feet wide, and the destructor house, 80 by 80 feet, and in addition to these, bath rooms are provided for both the engineers and the men. The destructor house contains 12 cells, each having 25 square feet grate area, and six Babcock & Wilcox watertube boilers, each with 1300 square feet of heating surface.

It was anticipated that to deal with the parish refuse and all the trade refuse to be obtained would require the constant use of ten cells. Experience has shown, however, that eight cells will take care of all the refuse obtainable, and the Vestry is already considering the feasibility of treating refuse from neighbouring districts.

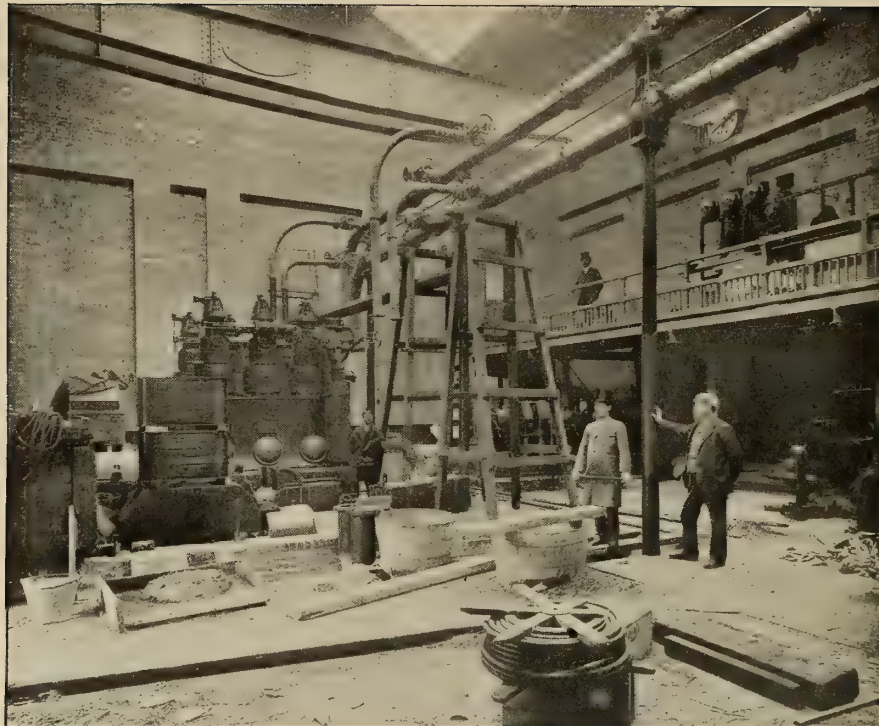
There is as yet but a single thermal storage vessel, 35 feet long by 8 feet diameter, which, with the boilers, is designed to work at a pressure of 200 pounds per square inch. Both boilers and storage tank are provided with duplicate fittings throughout, to guard against breakdowns.

The destructors are worked with forced draught produced by three electric fans, calculated to deliver 8000 cubic feet of air per minute at a maximum ash-pit pressure of three inches of water. The gases from the cells pass out of each cell at the front, thence through the boilers into either of two main flues leading to settling chambers where any suspended dust is allowed to settle, and thence pass up through a chimney, 150 feet high by 7 feet internal diameter at the top.

Each boiler is provided with a separate damper by which it may be connected with, or shut off from, its adjacent cells, and so arranged that it may be fired independently with coal or other fuel. The cells, too, may be worked independently of the boilers, if desired, by allowing the gases to pass out at the rear instead of at the front.

In handling such an inferior fuel as garbage, it becomes necessary to avoid manual labour as far as possible, and at Shoreditch the handling therefore is done mechanically by means of electrically operated elevators which raise the stuff to a tipping platform, whence it is conveyed by electrical charging trucks which deliver to each of the cells operated, from eight to twelve tons of refuse per day.

The generating plant consists of three Crompton generators coupled to Willans three-crank engines, each having an output of 160 kilowatts at 1100 volts; and three low-tension generators, similarly connected, each having an output of 70 kilowatts at 165 volts. The Willans engines of both sizes have been specially arranged with automatic ex-



THE HIGH-TENSION ENGINE.

pansion gear, so that economical results and good governing are obtained when working at any pressure between 200 and 120 pounds.

A motor-generator with an output of 60 kilowatts on either side is installed in order to enable either a high-tension current to be produced from the low-tension generators, or to transform down the high-potential currents to low-tension, thus enabling either the high or low-potential generator to be used for either service during light load or to supplement the other during heavy load.

In the accumulator room there is a battery of Pritchetts and Gold's accumulators having a discharge rate of 170 ampères for six hours at 165 volts, or 272 ampères for three hours, or a maximum discharge rate for a short time of 350 ampères. In order to complete the charge of these accumulators, a "booster," capable of increasing the electromotive force of the charging current by 75 volts, has been installed. In connection with this undertaking, the plans call for three substations to start with in various parts of the parish. Of these, one, the principal substation, at the junction of Curtain Road and Great Eastern Street, is already finished and in operation. This contains three motor-generators, each of which has on its low-potential side an output of 400 ampères at 165 volts which is transformed down from 1000 to 1100 volts.

These motor-generators are worthy of note on account of an ingenious starting arrangement by which an excessive starting current is avoided. This consists of an extra winding on the fields, in series with the incoming current at starting, but which, by an automatic switch, actuated by the stray field magnetism when the fields have become sufficiently strong, is short circuited.

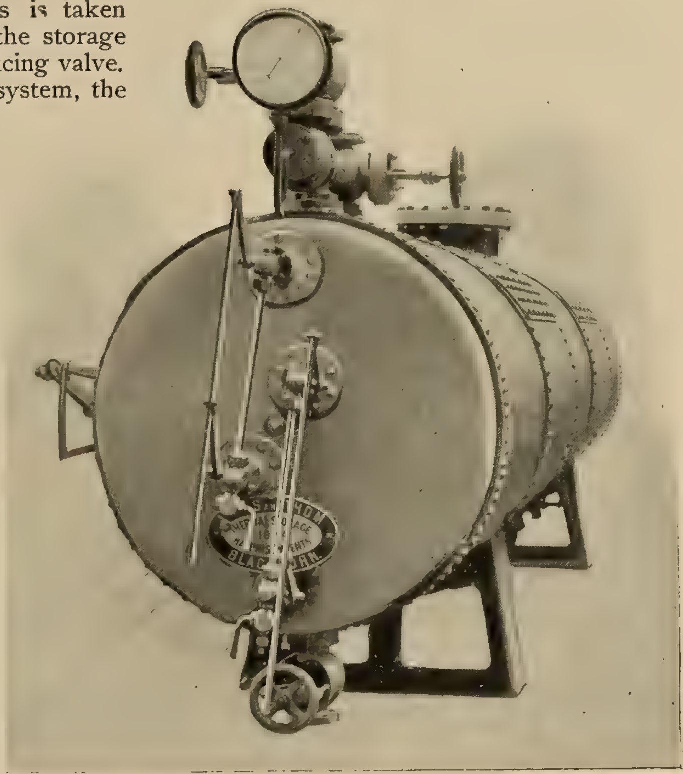
Eventually, this principal substation

will contain four of these motor-generators and each of the substations will become the centre of a low-tension network of distribution.

Referring again to the thermal storage: Mr. Halpin has devised three different methods which are severally known as "steam storage", "feed storage" and "combined feed and steam storage". In the steam storage system the boiler is kept completely filled with water and the storage tank is kept nearly so. The two are in free communication by means of pipes, and a constant circulation of water is maintained between the two; but the steam for the engines is taken only from the top of the storage tank through a reducing valve. In the feed storage system, the excess of energy during light load is stored in the tanks as before by raising the temperature of the water to a high degree. The boilers in this case are not completely filled and the steam is taken exclusively from the boilers, the superheated water in the tanks being used during heavy loads as feed water to the boilers. By this arrangement the thermal storage cylinder acts as a water purifier, and the boilers, by reason of the superheated feed water, are able to evaporate about one-third more water than would be possible were they fed directly by the water mains.

The third method, as the name would imply, is a combination of the first two. In this the pressures in the tank and boilers are equalised by connecting the steam spaces in both by pipe, and the steam for the engines is, therefore, taken from both. In other words, the thermal storage tank and boilers work in parallel. At the Shoreditch station the feed storage method is the one employed.

Combined with the lighting station, the Shoreditch Vestry are providing a fine set of public baths and washhouses as follows: — A first-class swimming bath, 100 feet by 40 feet; a second-class swimming bath, 75 feet by 35 feet; 20 first-class (men's) full-size slipper baths; 36 second-class (men's) full-size slipper baths; 5 first-class (women's) full-size slipper baths; 15 second-class (women's) full-size slipper baths; an establishment laundry with 18 drying horses and 2 centrifugal wringers; a public washhouse with 50 washing stalls, 50 drying horses and 4 centrifugal wringers and other machinery complete.



A HALPIN HEAT STORAGE TANK.

The hot water for all of these, the power for the machinery and the light, are all supplied from the destructor station.

There is already a very complete library in the Vestry of Shoreditch and another one nearly completed, a municipal technical school and a museum, all of which are lighted by the current from this same destructor station, and the fans, already mentioned as part of the equipment of the station, are connected with the sewer system, and thus, while producing the required forced draft for the destructor furnaces, at the same time ventilate the sewer system of Shoreditch.

The prices fixed by the Vestry are 4d. per unit after the first two hours (for which 6d. per unit is charged) and 2d. per unit in the day time for motive power, or 3d. per unit for all hours, the charges being determined by the Wright system of maximum demand, which is described further on.

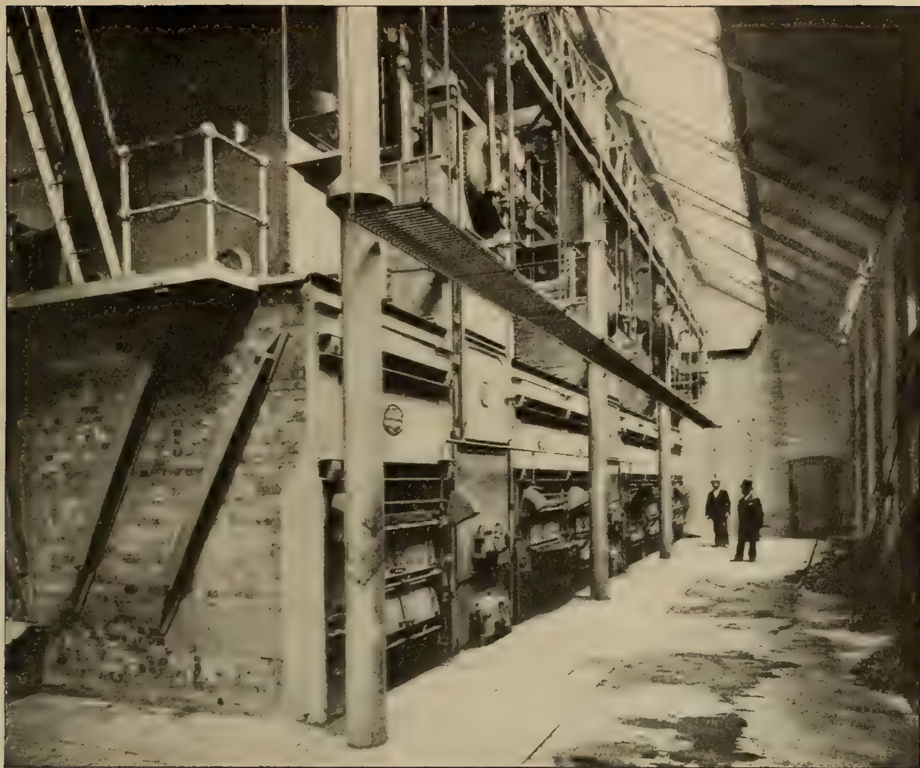
There are at present connected with the station 60 arc lights for public lighting and the equivalent of 7000 8-candle power incandescent lamps, with additional orders coming in faster than they can be handled. In fact, so large has been the demand, that steps have already been taken looking to the installation of additional engines to be ready by next February. It is a unique experience that a station, not yet five months old, finds its total capacity inadequate to the demands.

Interesting as this undertaking is from the nature of the fuel used, it will be not less interesting by reason of the numerous innovations introduced in the administration of its affairs. Some of these had previously been introduced in England, but in the United States they are entirely new. For instance the Wright system of charging according to the maximum demand of a customer has never yet been tried in its purity in America, but is in successful operation in 36 cities in England.

This system, which was first introduced in Brighton by Mr. Arthur Wright is, in brief, as follows:—By means of a peculiarly constructed meter the maximum demand which any customer makes upon the central station during a given time is registered. This represents how much of the plant must be kept in readiness for that customer. Whatever proportion of the total capacity of the station this happens to be is the proportion of the total fixed charges which that customer is required to pay, this, whether the maximum demand be for one hour in the month or for five or six hours a day. Every customer, therefore, be he large or small, pays his full share of the cost to prepare the central station to meet his maximum demand.

A second charge is then made to cover the cost of the current actually used plus a sufficient percentage to allow for a sinking fund and dividends. Thus, for instance suppose that the maximum demand of a given customer were such a proportion of the total station output that his share of the fixed charges is say, 6d. per day, he is charged 6d. per day whether he uses the current or not and an additional charge is made for the current actually used. Thus if 3d. per kilowatt-hour is sufficient to cover the sinking fund and dividends and the current meter shows that one kilowatt-hour per day has been used, the bill for that day would be $6+3=9$d.; if 2 kilowatt-hours, $6+(2\times3)=12$d.; if 10 kilowatt-hours, $6+(10\times3)=36$d. and so on. Thus it will be seen that while both the small and large customer equally pay their full share of the fixed charges of the station, the large customer gets his current cheaper than the small customer by reason of the lesser relative importance of the maximum demand charge. This is the general system of charging at Shoreditch.

The Vestry have also introduced several other interesting innovations. They have, for example, concluded a contract with the "Electric Extension Syndicate" for the supply of current through penny-in-the-slot meters. These meters are put in with electrical fittings without cost to the consumer, who is charged 6d. per unit for all hours. To reach another class of cus-



THE DESTRUCTOR CELLS AND BOILERS.

tomers they have contracted with the "Electric Free Wiring Syndicate" to wire apartments and supply fixtures free of cost to those preferring to pay ¾d. per unit more than the Vestry's actual charges for the registered supply.

And still another innovation has, the writer believes, been considered, but not yet adopted, viz., what is known as "the free supply of lamps." This is a plan first adopted by Mr. Gibbings at Bradford and is intended as a measure to insure prompt settlement of bills. The title "free supply of lamps" is, in a sense, a misnomer, for the plan simply involves a rebate for prompt pay in which the rebate takes the form of additional lamp bulbs instead of cash or a discount on the bill. Thus by this system a customer is entitled to a new 16 candle power lamp for every 1000 lamp-hours or 60 units charged on his bill (equivalent to a discount of about 7 per cent.), provided the bill is paid within a short interval of its presentation.

Thus, it will be seen that this station is unique in many respects and therefore interesting beyond the usual from very many points of view. Just what the economic results have been it is too early to state, but all of the work which it set out to perform has been accomplished with no other fuel than the kitchen garbage collected from the Vestry of Shoreditch. There has, indeed, been used a little coal on bank holidays and Sundays when no collection of refuge is made, but the amount has been insignificant; from July 1st to September 1st 34 tons of coal only have been consumed, this period including eleven such days of non-collection, or an average of about 3 tons per day.

The performance of these destructors is in marked contrast with that of the

destructors in use at Hamburg, in Germany, which constitute the largest garbage cremation disposal works in the world. At Hamburg, the cremation of the garbage until recently scarcely generated enough steam to create the forced draft necessary for the proper operation of the furnaces. Improvements were recently introduced, however, so that now the 36 cells produce enough power to drive two centrifugal blowers, each requiring about 16 horse-power, several electric cranes, a clinker crusher and sieves, and to supply current to 14 arc lamps and 62 incandescent lamps of 25 candle-power and leave an excess for other purposes of about 100 horse-power.

Formerly Shoreditch vestry had to pay 3s. 2½d. per ton for barging the refuse away, but now it is estimated that it costs only 1s. 2½d. per ton for burning it in the dust destructor. As the quantity of refuse obtained per year is about 22,000 tons, it will be seen that the saving in expenses of disposal of the refuse amounts to about £2200.

While, as before stated, the plant has not yet been in operation sufficiently long to allow the officials to divulge any figures as to performance, those who have watched it closely are convinced of its entire success from all points of view. In fact Lord Kelvin is quoted as having endorsed the plan unequivocally, and the Council of Gloucester have decided to apply to the Local Government Board for sanction to borrow a sum not exceeding £50,000 for the purpose of building in that city a similar plant, and the Fulham Vestry have, it is said, decided to do the same.

The last available report of the New York Street Cleaning Department shows that for the year 1895, 1,582,287 cart loads or 4958 boat loads of garbage were taken out to sea at a cost for collection and cartage of 65 cents, and for final disposition on boats of 29 cents, or a total of 94 cents per cart load. If we assume that a cart load weighs about a ton we have a means of comparison with Shoreditch and Hamburg, at which latter place it cost 35 cents per ton to run it. If, therefore, instead of dumping at sea, the lesser haul to the cremation plant would permit the treatment of the garbage for 50 cents a ton, there would be a saving of 44 cents per cart load or an aggregate of about $696,206. There were, however, 36,196 cart loads of garbage collected, but not included in the above figure which, at the same rate, would increase the savings to about $712,132. This is equivalent to the interest at 6 per cent. on a capital of $11,868,675, or more than sufficient, if judiciously invested, to light the whole of Manhattan Island with electric lights.

HYDRAULIC CRANES.

By Robert Gordon Blaine.

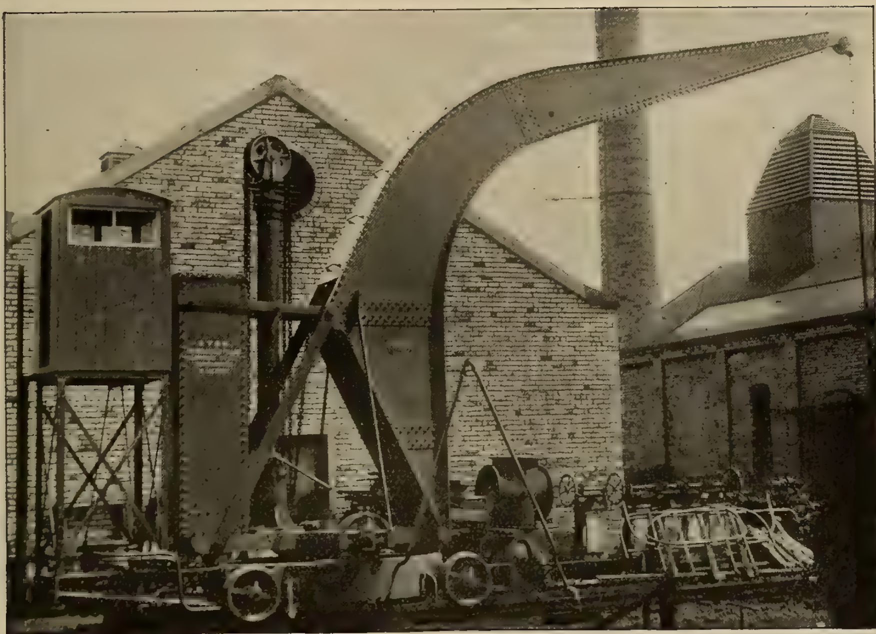


FIG. I. A MOVABLE TWO-TON CRANE WITH "WALKING" PRESSURE PIPES.—(SEE PAGE 127.)

WHEN the history ot engineering enterprise, during the Victorian era, comes to be written, no department will give records of greater interest than that dealing with applications of hydraulic power. Along miles of busy wharves, in city warehouses, in steel works and foundries, and in workshops, water under pressure is, for many operations, the silent agent employed for the transmission of power. In London alone there are, now, about ninety miles of hydraulic mains laid in the streets, and the use of hydraulic power is rapidly extending.

In our admiration of modern successes, however, we must not forget the work of those pioneers whose genius and efforts made later success comparatively easy. To Lord Armstrong is due the credit for the imitation of the at that time new departure in the transmission and application of power. Though now the head of the largest engineering works in Britain, if not the largest in the world, yet he did not begin professional life as an engineer, nor had he the training which engineers nowadays consider essential to success.

Immediately after his early school days he was articled to Mr. Donkin, subsequently became a partner in the firm of Donkin, Stable & Armstrong, solicitors, of Newcastle-on-Tyne, and practised as a solicitor for some years. The intricacies of the law, however, possessed less attraction for him than the study of natural science, to which he

devoted most of his leisure time. In his professional journeys through the Yorkshire hills, instead of puzzling his brain with legal quibbles, he seems to have been more occupied with schemes for utilising the great stores of energy so lavishly bestowed by nature in the mountain streams which beautified the landscape. With the genius of a true engineer he sought for efficient methods of employing these gifts,—in an engineering sense,—for "the use and convenience of man."

In a letter to the *Mechanics' Magazine* in 1840 he called attention to some of his plans, and pointed out that water possessed many advantages as a medium for the storage and transmission of power. He showed that if water were pumped by a steam engine into an elevated reservoir, a large portion of the potential energy thus given to the water could be obtained from it again, and, further, that a small steam engine, working continuously, might supply many machines working intermittently.

Up till then, however, there existed very few, if any, machines suitable for operation by water at pressures such as he contemplated, low as they were, compared with the pressures now common. His first invention was a water wheel, capable of efficiently utilising water flowing under considerable head or pressure. A model of this wheel was made, but though it fulfilled the expectations of the inventor as regards efficiency, it never came into general use. His next invention was the hydraulic crane, which has since developed into various forms in the hands of many makers, and is used under a variety of circumstances.

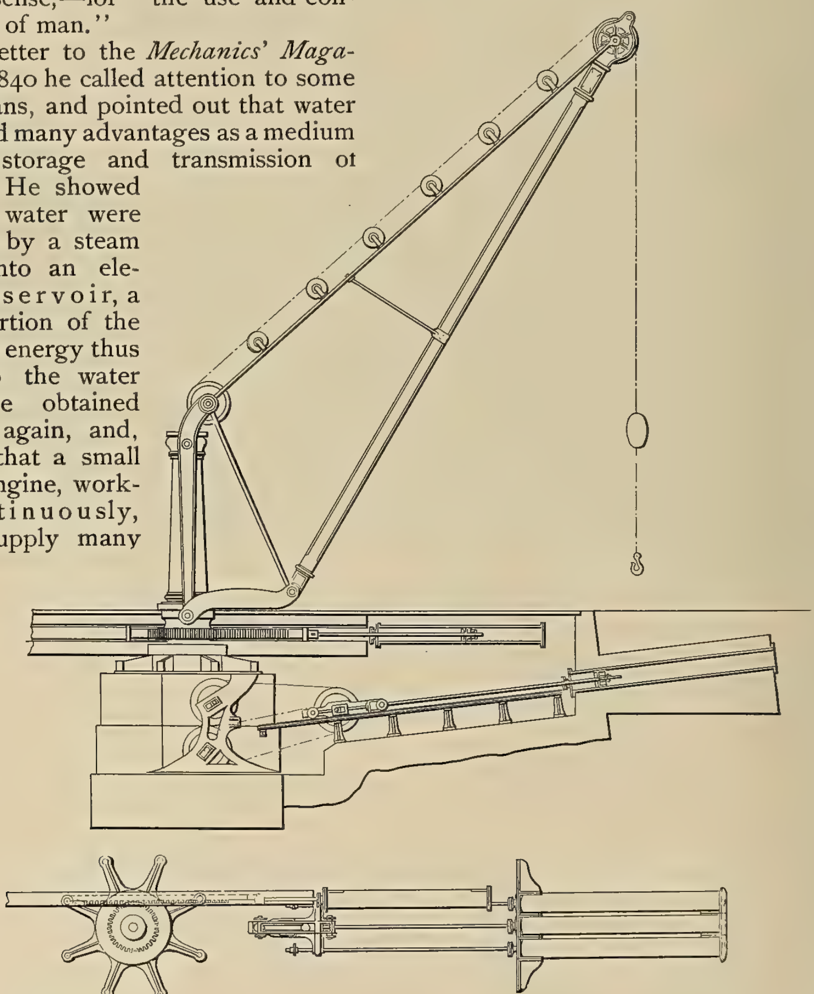


FIG 2. LORD ARMSTRONG'S FIRST HYDRAULIC CRANE.

Being aware that hydraulic power is best adapted for giving a slow steady

FIG. 3. A CRANE FOR SHIPBOARD USE.

motion, he devised a means of magnifying, by a system of pulleys around which passed the lifting chain, the motion of a piston working in a hydraulic cylinder, somewhat like an elongated hydraulic press. There is no doubt that Bramah, who had perfected the latter machine about 1802, foresaw some of the modern applications of hydraulic power.

In a paper read before the Institution of Civil Engineers in London, in 1850, Armstrong thus described his new machine:—"In order to lift the weight, the water is admitted into a cylinder by means of a slide-valve and exerts its force upon a piston. The rod of this piston is connected with the hoisting chain, so that when the piston recedes from the pressure, the weight is lifted. The chain, however, is not simply fast-

FIG. 4 A MOVABLE DOCK CRANE.

ened to the piston rod, for, in that case, the height to which the weight could be lifted would be limited to the length of the cylinder; but instead of this it makes two or more folds over pulleys which operate in such a manner as to increase the travel of the chain in proportion to the number of folds. When the weight is to be lowered, the water is allowed to escape by a different movement of the same valve, and the speed, both in lifting and lowering, is graduated by the extent to which the valve may be opened." He then went on to explain his method of turning the crane by a smaller cylinder, the piston of which was fitted with a rack, working into a spur wheel on the base of the crane post.

In Fig. 2 are given two views of Lord Armstrong's first crane. These will be readily understood from the description given above. It will be seen that there are three lifting cylinders with pistons attached to one cross-head. One, two, or all, of the cylinders may be used at will, and thus the power of the crane, and the consumption of water may, to a certain extent, be graduated as required. This crane proved very successful, but was not publicly installed for some time.

In 1846 one was erected on Newcastle Quay, being supplied with water from the ordinary town mains. It excited great interest. Engineers came from all parts of the country to see it, and the result was that similar cranes were soon afterwards erected at Glasgow, at the

Newcastle station of the York, Newcastle and Berwick (now the North Eastern) railway, and at the Albert Docks at Liverpool. It was soon found that the pressure of the ordinary domestic supply was not, in all cases, sufficient nor reliable; hence, pumps with air vessels were used to give the requisite pressure. This not proving altogether satisfactory, and the cost of a water tower of sufficient height being, in some cases, prohibitive, the hydraulic accumulator was devised. This proved the crowning success in Lord Armstrong's system, and made later developments of hydraulic power supply comparatively easy.

A warehouse crane usually consists, as shown in Fig. 6, of a bracket-shaped frame, resting in bearings attached to the outside of the wall of the building. It can turn, usually, through 180 degrees, but in some cases the supports project some distance from the wall, thus allowing a greater angular movement. The lifting and turning cylinders are attached to the inside of the wall. The latter are comparatively short, owing to the limited range of motion. As the loads are usually small, with high lift, the ratio may be as great as 8 to 1, but the greater the number of pulleys, other things being equal, the smaller the efficiency of the crane. Simpler forms, in which the load is slewed by hand, are often used.

Fig. 5 shows a platform crane, such as is used at railway stations, the form shown being adopted where the position in which the crane is placed allows the top socket, in which the pillar turns, to be attached to a roof or overhead floor. The lifting cylinder is in the centre of the pillar, which is turned by a pair of hydraulic plungers with multiplying sheaves, as shown, and chains acting on a drum on the bottom of the pillar. The lifting, lowering and turning valves are placed side by side, the water being conveyed, by a revolving joint in the bottom socket of the pillar, to the lifting cylinder. The crane lifts about thirty hundredweight.

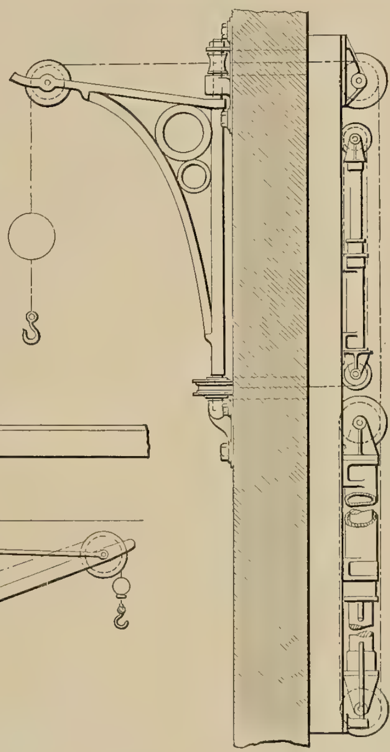


FIG. 6. A WAREHOUSE CRANE.

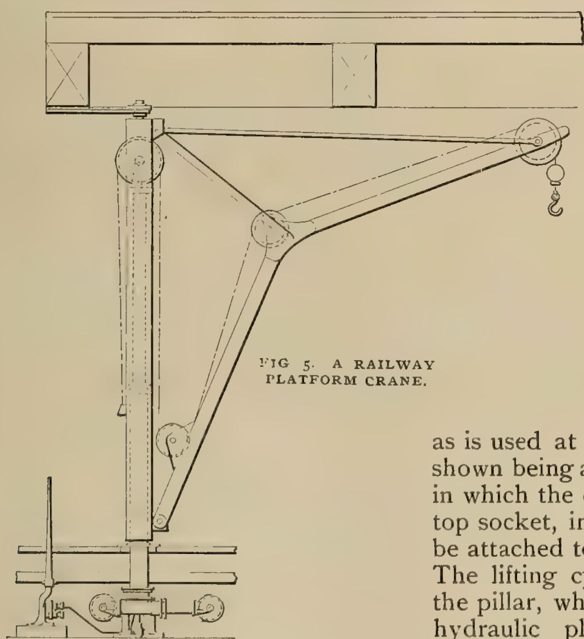


FIG 5. A RAILWAY PLATFORM CRANE.

FIG. 7. A CRANE MOUNTED ON A WAREHOUSE ROOF.

Formerly, in small cranes, the pillar itself formed the lifting cylinder, as in Fig. 3. This shows a type of crane used on board ships, a wire rope being used, instead of a chain, for lifting, and the drum on the pillar being "pocketed" to receive the links of the turning chain. It is more usual nowadays, however, to construct the pillar of steel or wrought iron and to place the lifting cylinder within it, as shown in most of the illustrations.

Coming to dock or quay cranes, movable cranes are usually employed, this type possessing obvious advantages over fixed cranes, as rapidity in loading and unloading are of first importance. Movable cranes can be placed to suit the different hatchways of a vessel, four or five being brought to bear on a vessel at the same time. For ordinary purposes a crane capable of lifting from thirty hundredweight to two tons is found to be most convenient, and various types of these are shown. The lifting cylinder is within the pillar in each

FIG. 8. A CRANE WITH ARCHWAY THROUGH PEDESTAL.

case, the multiplying power being usually 6 to 1 and the lift from fifty to sixty feet. In the one shown in Fig. 4 the turning machinery is in the pedestal, at the foot of the pillar, and is similar to that of the cranes already described, the turning cylinders, however, having greater power on account of the greater rake or radius of the jib. The pedestal is mounted on wheels which run on the rails, as shown, there being screw chocks fitted to the feet of the pedestal, which can be screwed down to take the weight off the wheels when the crane is at work. The valves are worked from a cabin on the pedestal, from which the man in charge has a good view of the work.

In the crane shown in Fig. 8 the turning cylinders are fixed on an inclined frame at the back of the pillar. The drum, being cupped to receive the links of the turning chain, is fixed to the upper bearing in which the pillar revolves. The pedestal is often constructed with an archway through it to economise space. Screw feet to take the weight are fitted as before, and there is usually a frame on the back of the pillar, carry-

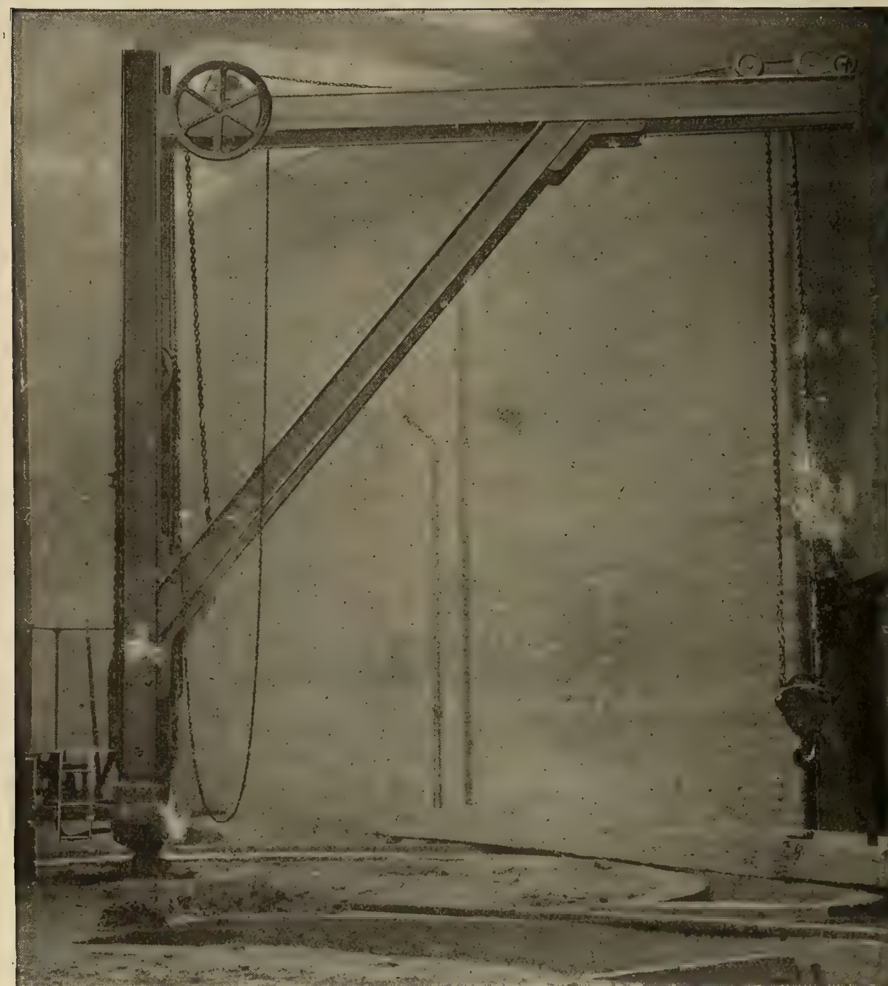


FIG. 9. A SMALL FOUNDRY CRANE WITH HAND TRAVERSING GEAR.

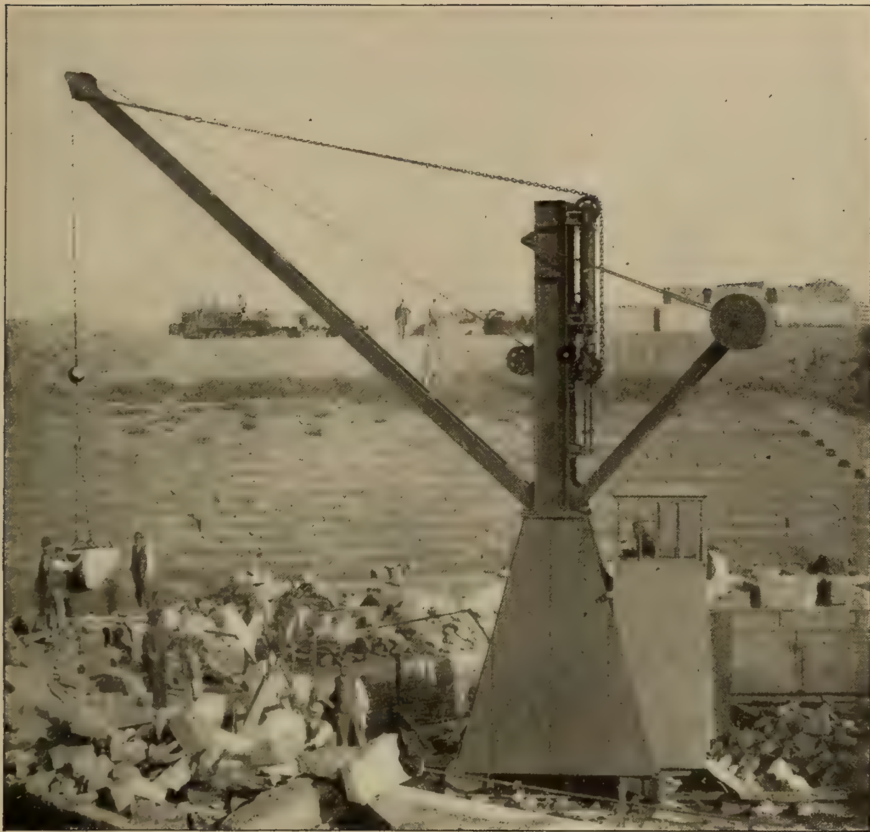


FIG. 10. A CRANE WITH LONG-RADIUS JIB.

ing sufficient balance weights to render the crane stable, even if loaded with twice the greatest load that it is designed to lift.

Makers have often to depart from their standard practice and adapt their design to the special circumstances under which the machine has to work. Thus, the crane shown in Fig. 7 is of special form, being designed to serve warehouses placed too near the quay wall to permit of the ordinary form of machine being used. The front carriage, which is of some length, runs on the parapet and is connected to the rear carriage by a wrought iron frame which contains the lifting cylinder, so that when the first carriage is moved along, the rear carriage, running on the ridge of the roof, must follow. The front carriage contains a drum on which wire rope is coiled; the other end of the rope being made fast, the turning of the drum by a hand wheel, or crank, hauls the crane along. Another crane may be used to do this hauling; the wire rope in that case, after passing through a leading block, is fastened to the second crane, the drum then merely serving to regulate the length of the rope. The jib turns through an angle of 180 degrees. The turning is effected in the usual way by a pair of horizontal cylinders, placed in the front carriage.

In cases where an exceptionally long rake or radius of jib is required, and where the radius must be variable at will, a topping or derricking motion is fitted as illustrated in Fig. 10. A special cylinder is fixed to the back of the pillar, the function of which is to support the jib-head and alter the radius of the latter

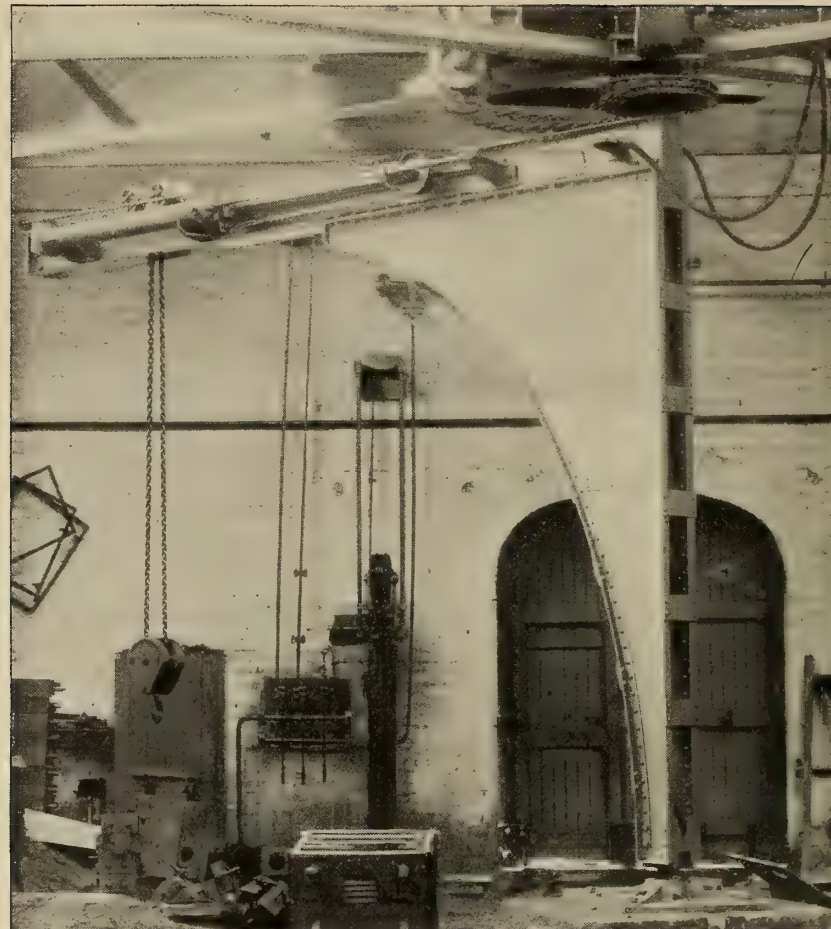


FIG. 11. A FOUNDRY CRANE WITH HYDRAULIC TRAVERSING GEAR.

Before proceeding to notice other types of cranes with high lifting power, a digression may be permitted in order that reference may be made to cranes of special form which have been developed by other firms than that of Lord Armstrong. The specimens to follow are all by the Glenfield Company, of Kilmarnock, N. B., with the exception of the "centre" crane of Messrs. Tannett Walker & Co., of Leeds. Fig. 9 shows a neat little crane for foundry purposes. The load is suspended from a little carriage which can be traversed, or moved along the horizontal tie, by the hand chain shown. The crane is also turned by hand, but the load is lifted by the ram of a hydraulic cylinder placed inside the pillar as usual. This crane is, of course, used only for small loads.

Fig. 11 shows a foundry crane of greater size and power. The load is traversed by hydraulic cylinders, fixed to the horizontal member of the jib. The lifting cylinder, in this case, is not attached to the crane, but is fixed against a wall of the building near the working valves, the lifting chain being led underneath the floor and up the pillar of the crane to the hook block over the sheave of which it passes, then over the lifting sheave, its end being fixed to the jib. The slewing cylinders are attached to the roof, the turning chain passing

over a pocketed drum on the pillar. A larger crane for foundry purposes is shown in Fig. 12. This machine is capable of lifting up to fifteen tons. In this case all the cylinders are attached to the crane. The lifting cylinders are in the centre of the pillar, the traversing cylinders being on the top member as before. The turning cylinders are just behind the pillar,—one is shown in the picture. The valve levers are operated from a little platform behind and to one side of the pillar. There are two lifting cylinders, one inside the other, the inner one forming the ram of the outer and having a ram of its own. The smaller of these rams alone is used for lifting loads up to seven and one-half tons. In these cases the motion of the lifting ram is magnified in the ratio of 4 to 1, and that of the rams of the slewing cylinders, as usual, in the ratio of 2 to 1.

A crane with variable radius, suitable for outdoor work about foundries and engineering works, is shown in Fig. 13. Here the lifting cylinders are inside the pillar, the derricking motion cylinder being behind it, the magnification of motion is, in both cases, 8 to 1. The turning or slewing cylinders are placed vertically, one on each side of the pillar at the foot of the latter, with a 2 to 1 ratio as before. The jib is seventy feet long and the lift fifty feet.

A hydraulic "centre" crane made by Messrs. Tannett Walker & Co., for use in steel works is, in many respects, unique. Three rams are employed; the lift of the body of the crane is equal to that of the load, the motions of the rams being directly transmitted to the load. The centre and largest ram supports the dead weight of the crane, one or both side

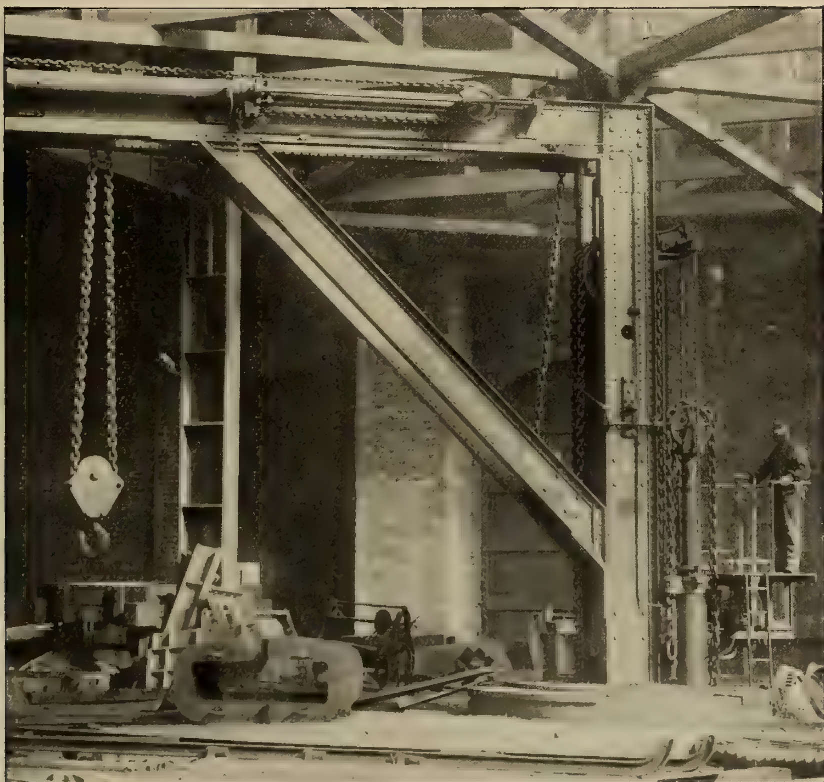


FIG. 12. ANOTHER FORM OF LARGE FOUNDRY CRANE.

FIG. 13. A CRANE FOR GENERAL OUTDOOR USE, MADE BY THE GLENFIELD COMPANY, KILMARNOCK, N. B.

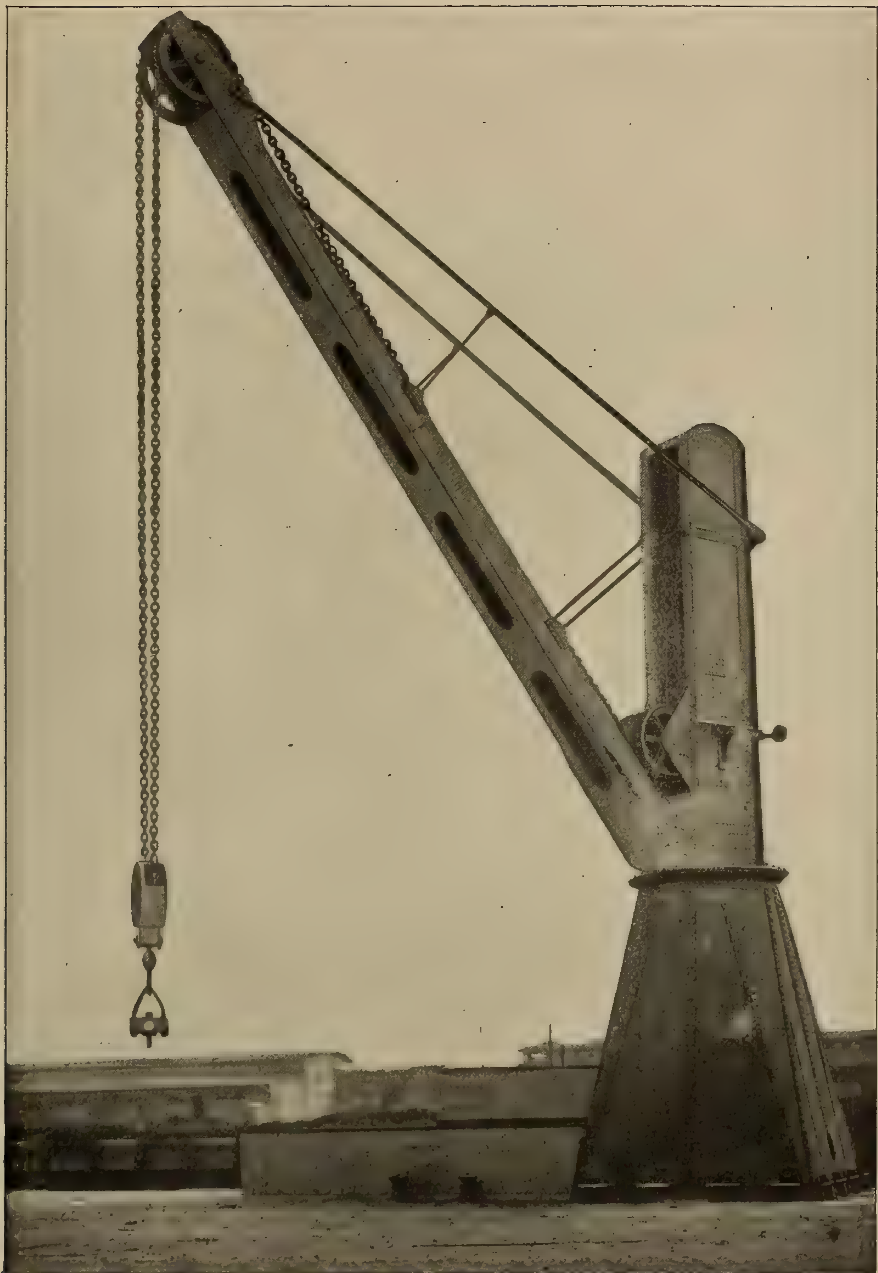


FIG. 14. A HEAVY, FIXED PEDESTAL QUAY CRANE, MADE BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-UPON-TYNE.

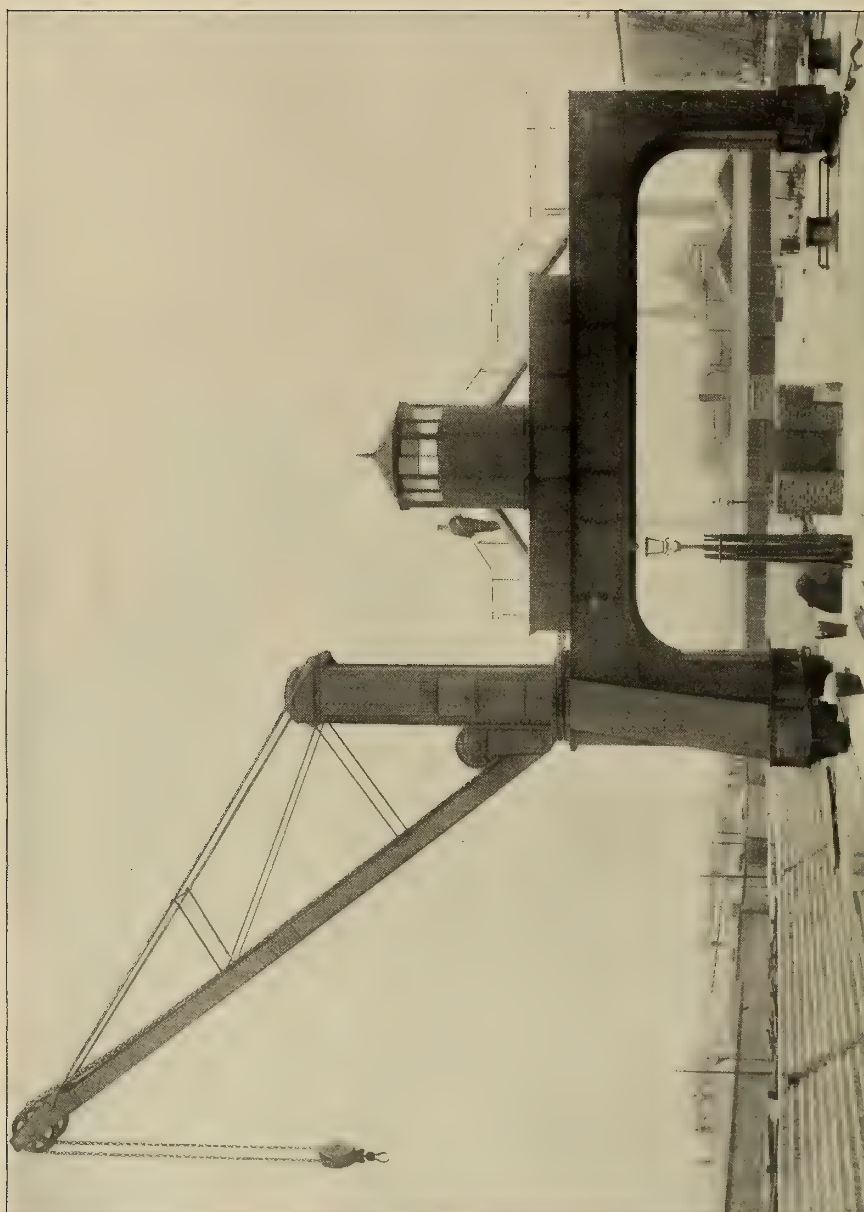


FIG. 15. A MOVABLE FIFTY-TON ARCHED PEDESTAL CRANE, MADE BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD.

rams being employed to lift the load. The side rams are calculated to lift the greatest net load. The jib is a horizontal beam supported, between rollers, in a framework attached to the top of the rams.

The crane lifts ten tons of molten steel, there being a ladle at each end of the jib. This jib, being movable between the rollers, can readily be drawn out to one side or the other, like an ordinary jigger, the radius being thus variable from 10 to 20 feet. The former is the radius when the molten metal is run into the ladle from the converter; the latter, that at which the ingots are run. As the deadweight of this crane is considerable, the arrangement results in a great saving of water, for, in the down stroke, the water under the centre ram is not exhausted, but goes back into the pressure mains.

In the ordinary ingot crane of the same makers, the jib is not variable in radius, the load being suspended from a carriage, which can be traversed on the horizontal member of the jib, but the arrangements for lifting and turning are the same as before.

Before closing this brief notice of foundry and engineering works cranes, a reference may be made to the small movable two-ton crane depicted in Fig. 1, on the opening page of this article. The view requires little explanation, except the statement that the tall rectangular tank which, with its contents, forms the balance weight, contains discs of cast iron which are easily moved into position. The pressure supply is led to the crane by "walking" or by telescopic pipes, the former being pipes which can swivel at certain joints so as to alter the distance apart of their extreme ends; these are seen in the picture near the base of the jib. Telescopic pipes, laid between the rails and underneath the carriage on which the crane rests, are sometimes used. The exhaust water is taken by armoured hose to the return mains.

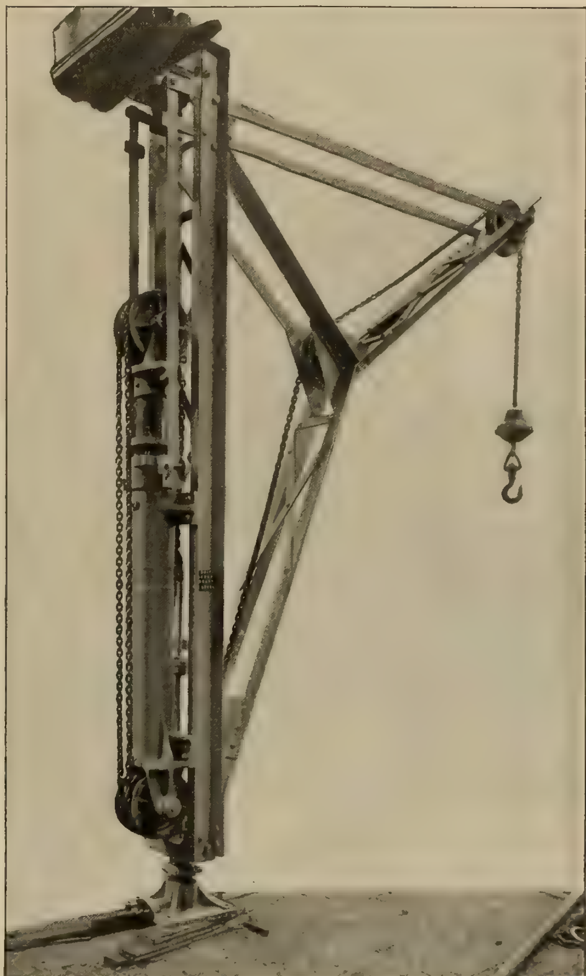


FIG. 16. A CRANE MADE BY THOMAS SMITH, RODLEY, LEEDS.

Resuming reference to the cranes made at the Elswick Works, we may take up the typical, heavy, fixed-pedestal quay crane, shown in Fig. 14. The lifting machinery is inside the pillar, which is mounted on a fixed pedestal se-

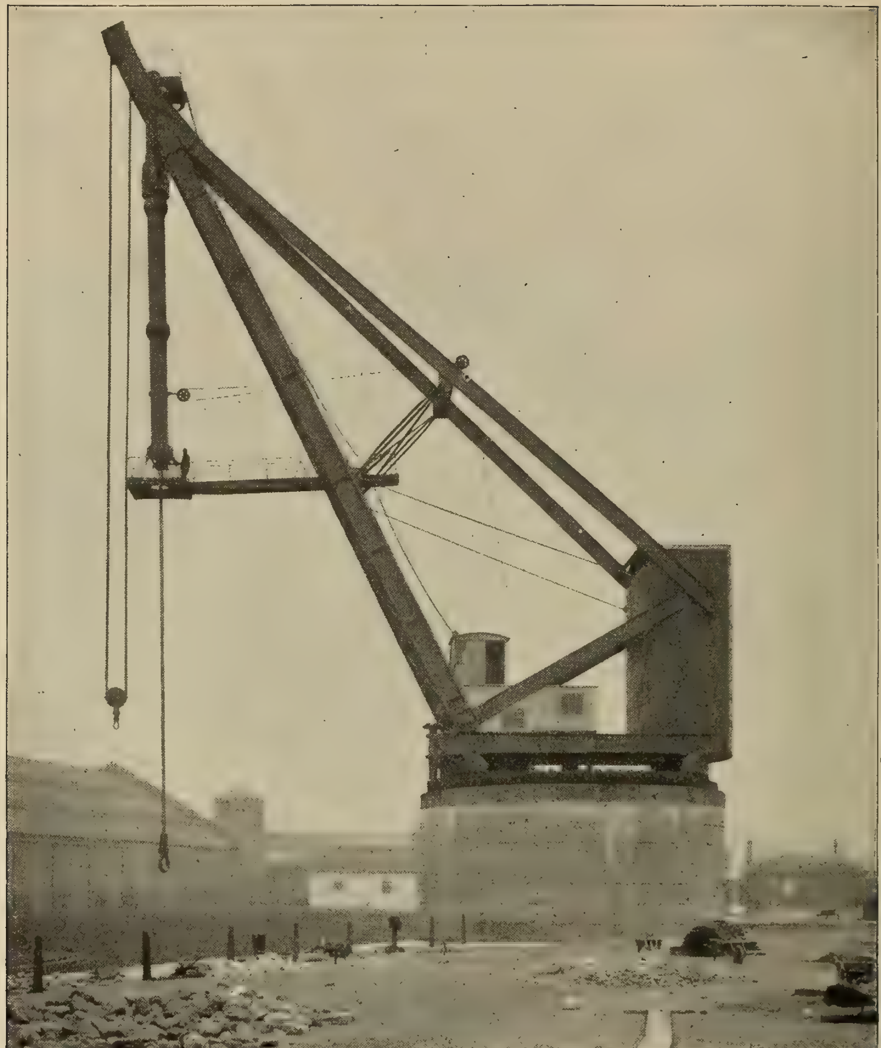


FIG. 17. A 100-TON ROLLER PATH CRANE.

cured to the quay with eight or ten strong holding-down bolts. The turning eylinders, which are of the usual type, are placed side by side in a casting in one side of the pedestal. It will be noticed that the lifting chain is double. This is to avoid the use of so large a chain as would be required to lift the weight on one ply, and not for the purpose of obtaining a 2 to 1 purchase as in many steam cranes. The pulley above the lifting eye is here used merely to provide for unequal stretching of the chain. Of course, the same range of power and lift could be obtained by fixing one end of the chain to the jib head, using a running block instead of the equalising pulley shown, and passing the chain around an increased number of multiplying sheaves; but the method adopted greatly reduces friction and the wear and tear of the chain. The upper bearing for the pillar at the top of the pedestal is usually fitted with anti-friction rollers. The crane lifts up to forty tons, the height of lift being fifty feet.

It may be mentioned here that in most hydraulic cranes, at least in those of large size, automatic cut-off gear is provided, which prevents over-travel of the lifting ram. This is usually effected by a projection from the ram which, when the ram reaches a point near the extremity of its stroke, strikes a tappet connected to the valve, closing the latter to pressure and preventing further movement.

The lifting power of this crane is variable in a way that has already been briefly noticed. The great defect of an ordinary hydraulic crane with non-variable lifting power, is that it requires the same amount of water to lift the empty load block or hook as the largest load which the crane is capable of raising. When, as in London, the pressure water costs from 1s. 6d. to 2 shillings per 1000 gallons, evidently the cost per ton of lifting small loads is considerable, and the efficiency of the crane is small.

Variation in the power of the crane and the consumption of water is effected in different ways. One method,—that of having three lifting cylinders, as in Lord Armstrong's first crane,—has already been referred to. Another method, formerly much used, and still employed in many cranes, is that of having the lifting ram shaped like a piston with a very thick piston rod. Full power is obtained by admitting the water to the full or face area of the piston, the other or annular area being open to exhaust. When the lower power is required, pres-

FIG. 18. A CRANE DESIGNED FOR WEIGHING THE LOAD RAISED.

FIG. 19. ANOTHER VIEW OF A WEIGHING CRANE, SHOWING THE TIPPING OF A COAL CAR.

sure supply is admitted to both sides of the piston. The pressure on the full area predominating, the load is raised, the water on the other side of the piston being forced back into the mains. Thus a net amount of water, equal only to the displacement of the piston rod, is used per stroke at the lower power.

Neither of these methods is now much in favour with the best makers. It is very seldom that more than two powers are required, and it is found more convenient to employ a cylinder with two concentric plungers, the outer one being hollow, and forming the cylinder for the inner one. Clamps are provided for holding back the outer plunger when light loads are dealt with, and when the crane lifts with full power both plungers move together, the inner one being inert. This is the method adopted in the heavy quay crane just noticed. The inner plunger works through a stuffing box on the outer end of the larger one and alone acts on the lifting chain and sheaves when the clamps,—which are operated by a hand lever on the side of the pillar,—are out of gear.

Relief valves should be provided in connection with both the lifting and turning cylinders. It is well known that a dangerous pressure may be developed when a rapidly moving load is suddenly arrested by unyielding water through the sudden closing of the exhaust valve. It is not difficult to give a rule by which

such pressure may be calculated, if we assume the stoppage to be absolutely instantaneous and the containing cylinder perfectly rigid. What the pressure will be in any given case cannot be calculated with anything like accuracy, as it depends on the rate of stoppage of the flow, and the amount of yielding of the cylinder. The latter factor is readily found in terms of the pressure when the material is given. Whether we can determine it or not, however, it is well known that a very considerable, and in some cases dangerous, increase of pressure may be thus produced.

Cranes of the type shown in Fig. 15 are made up to a lifting power of fifty tons, and are sometimes constructed with arched pedestals, large enough in span to allow locomotives to pass through. In some cases the pedestals are fitted with hydraulic travelling gear by which the crane is moved along the quay or railway. In the crane illustrated, hand gear is fitted, consisting of an arrangement of wheels and pinions, gearing into the travelling wheels of the crane pedestal. This gear is contained in the lower portion of the pedestal at each side, being actuated by an ordinary removable crank handle. The capstans shown in the cut are driven by three-cylinder hydraulic engines, and are used for hauling trucks and sometimes for moving vessels, or for pulling the crane.

For cranes of very great lifting power, the roller path type of crane is usually adopted, either with chains or wire rope, as usual, or with direct-acting cylinder as in Fig. 17. The lifting power of this crane is 100 tons, and the length of the lift of the direct-acting cylinder is fifty feet. The rake, or radius, of the jib is fifty-five feet. The crane is mounted on a ring of "live" rollers and is turned by a rotatory hydraulic engine, with gearing acting on a circular rack. The lifting cylinder is slung in gimbals from the jib head, and an auxiliary chain purchase, capable of lifting thirty tons through ninety feet, is provided for the smaller loads. The direct-acting cylinder is slung in toward the jib when this purchase is in use. A similar type of crane, capable of lifting 160 tons through forty feet, has been constructed by the Elswick Works, the chain purchase having a lifting power of forty tons, with a range of ninety feet lift.

A very important application of hydraulic power is that which deals with the shipment of coal. Cranes designed for lifting coal or minerals, are often fitted with weighing gear. This may be either of the hydrostatic kind in which the sheave bearing the load is supported by a plunger resting on water in a small cylinder, the pressure of this water giving the amount of the load, or the crane itself may be constructed for weighing as shown in Fig. 18. In this case the jib head sheave is not mounted directly on the jib itself, but on a steel yard pivoted near the end of the jib, the inner end of the steel yard being attached to a spring balance which is graduated to show the load on the crane. The weight of the steel yard is counter-balanced by a weight on a short lever, whose fulcrum is on the jib not far from its lower end.

Figs. 18 and 19 show a very interesting form of hydraulic crane for lifting a truck containing coal, and tipping it over the side of the vessel. The truck rests on a cradle on to which it is run from the railway to the cradle resting on the rails, and itself bearing rails which join the former so as to present little obstacle to the truck's motion. The lifting of the whole apparatus is performed by the outside pair of chains which are actuated by a separate cylinder from that which controls the tipping, this being performed through the medium of the centre chain which separates above the swivel, its two portions from this point passing over conveyance pulleys on the lifting beam above the cradle. They are attached to the rear end of the cradle, the arrangement being such that not only the lifting, but also the tipping chains are permanently attached to the cradle.

When the cradle is tipped, the rear sling chains hang slack, as shown in Fig. 19. The lifting cylinder is placed in the pillar, and the tipping cylinder is the central cylinder on the frame at the back of the pillar, the two outside cyl-

inders on this frame being those for turning. To prevent the truck from running forward on the cradle when the latter is tipped over the ship's side, a pair of hooks engage one of the axles of the truck. These hooks are mounted on a shaft, which can be turned so as to disengage the truck.

In this brief notice of hydraulic cranes enough has been given to dispel any idea that the efficiency of hydraulic cranes can be readily stated as so much per cent. The types of cranes are so varied, and the efficiency depends on so many different circumstances, such as the state of the packing, the number of sheaves, etc., that no general rule is possible.

One might say that probably the efficiency varies from 50 to 90 per cent., depending on the type of crane and its working condition; but this statement is vague. Some writers give the efficiency in terms of the number of sheaves, but this can only be even approximately correct for one particular type of crane, and when all the specimens of that type are in pretty much the same state.

THE MANUFACTURE OF COAL BRIQUETTES.

By Arthur J. Stevens.

DURING the last few years the value of small coal raised in collieries and the waste that has been going on for a long period of years, has begun to be generally recognised. In the getting of coal it is unavoidable that a certain proportion should be in the form of small coal; it is impossible that the coal should be cut in blocks without a certain amount of breakage taking place. The proportion of this small coal varies between wide limits in different collieries and with different seams. In some collieries, especially in the East of England, it is not unusual for 7 per cent. of the coal brought to the surface to be in the form of small. Until within the last thirty or forty years nearly the whole of this coal was thrown upon the waste heap; but in bituminous and semi-bituminous districts it is now being utilised to a large extent in the making of coke, and in the manufacture of patent fuel, or coal briquettes.

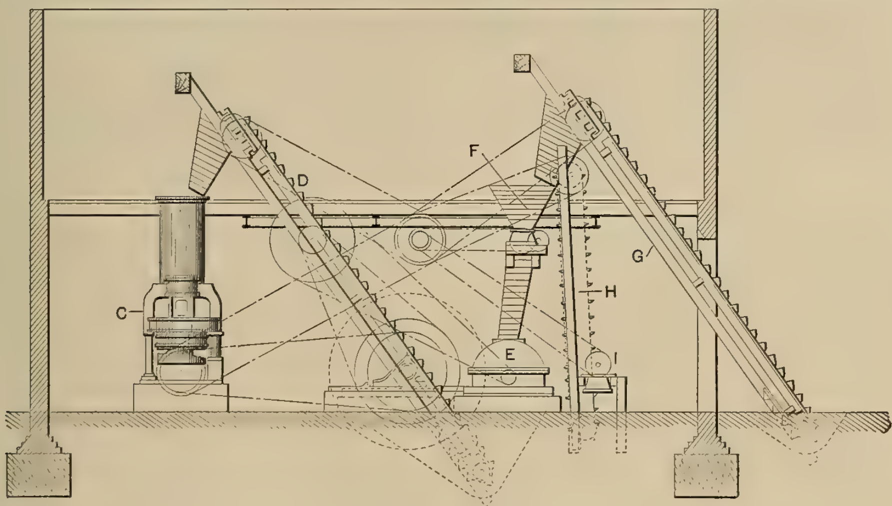
Although this manufacture has been carried on within certain limits for a long period, it is only within the last forty years that the trade has begun to attain its present large dimensions. Patents have been taken out for the manufacture of briquettes from the time of Elizabeth, and every possible and impossible material has been suggested as an agglomerant to bind small coal together. Pitch, however, which is the residual product of the distillation of coal tar, is the only material which can be said, at present, to be used on a commercial scale for this purpose. The process of manufacture consists in mixing small coal with a certain proportion of ground pitch which will vary with the quality and character of the coal to be worked up, and of heating and pressing the mixture into blocks of suitable size.

The arrangement of such a plant will be understood by reference to the elevation of a 50-ton fuel plant on the opposite page. In this the small coal is received from the railway wagon and thrown

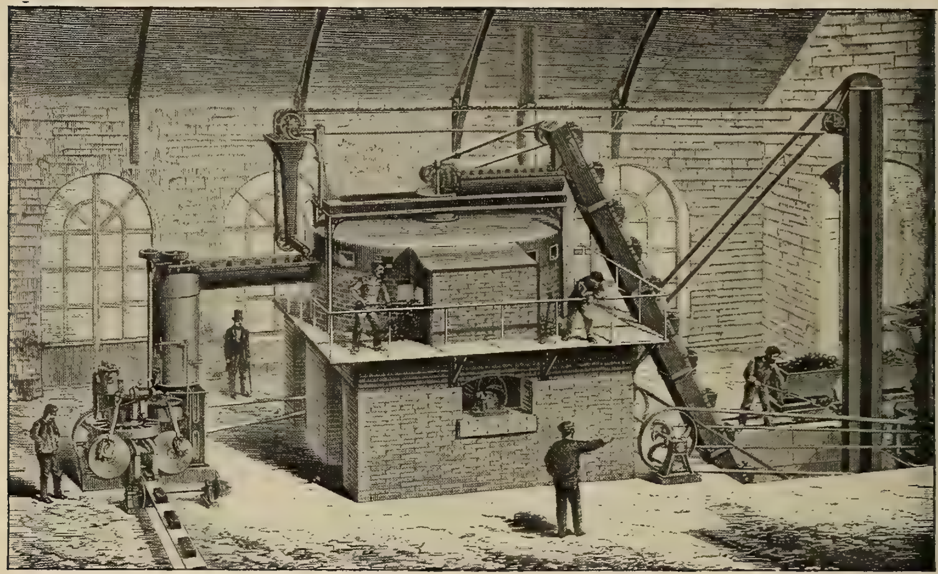
into the pit of the elevator *G* by which it is raised to the first floor of the works. At the same time the pitch is thrown by shovel into the pitch mill *J* in which it is roughly ground, and reduced to a size which is easily capable of measurement. The roughly ground pitch is then raised by the elevator *H* to the first floor, and coal and pitch are thrown into the separate compartments of the hopper of the distributor *F*. The latter is a machine for proportioning the right quantities of coal and pitch.

The pitch and coal thus measured fall down into the hopper of the disintegrator *E* where they are ground and thoroughly mixed, the duty of the disintegrator being quite as much to intimately mix the ingredients as grind them; in fact fine grinding is a mistake, and for patent fuel purposes the coal should not be ground into anything like a powder. The coal and pitch being thus ground and mixed fall down into the hopper of the coal elevator *D* and are deposited into the pugmill of the fuel press *C*. In this pugmill, by means of the introduction of steam, the pitch is melted during its passage through; next it falls into the feeding pan of the machine and is then passed into briquettes, and these can be carried away from the machine either by a shoot, or a belt, or by loading on to trolleys, or by any other means that may be locally advisable.

Of the fuel press a sectional elevation is given on page 135. In this *A* represents the pugmill in which a set of steel arms are constantly revolving. This mill is provided with a suitable number of steam jets, the steam from which should be of about 60 to 70 pounds pressure and free from water. The coal and pitch which are introduced into the top of the mill are gradually passed down by means of the revolving arms, and during the passage the pitch is melted by the steam with which it comes in contact. The mixture of coal and pitch, or paste as it is sometimes called, then falls into the feeding pan of the machine, from which it is forced by the arms in that pan into the moulds marked *D* which are cast in the die table of the machine. This die table is usually made with ten moulds, either for making one or two briquettes per stroke, as may be arranged, and is pushed around, one mould at a time, by means of a strong wrought iron pushing arm. When the full mould reaches the position shown in the cross section, steam is admitted automatically underneath the piston in the cylinder *C*; this



A TYPICAL ARTIFICIAL FUEL PLANT.



INTERIOR OF A FRENCH ARTIFICIAL FUEL PLANT, WITH A DOUBLE COMPRESSION PRESS.

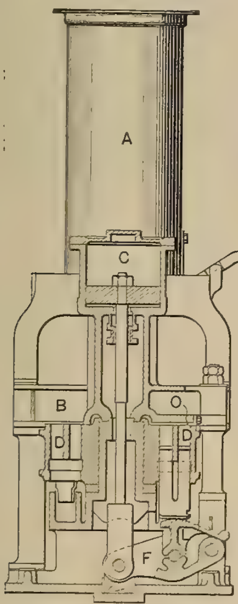
raises the lever *F*, and, pressing against the pressure plate *O*, forms the briquette. The table then continues its travel, one mould at a time, and the pressing pistons, travelling up an inclined plane, gradually force the briquette to the surface of the table, whence it is moved on to a shoot, or travelling band, by a movable arm.

This machine is the class of machine used throughout South Wales, which, as is well known, is the seat of the artificial fuel trade in England. It has been improved and modified of recent years, and possesses the merit of extreme simplicity and freedom from breakdown. The principal feature in this machine wherein it differs from many others in the market, is the fact that every mould carries a pressing piston of its own, and consequently no pressing piston *enters* a mould in order to compress the coal. In a machine to work such rough material as coal, it is almost impossible to ensure that a mould table shall stop at any exact point required; but in this machine this is unnecessary as from the fact that each mould carries its own pressing piston, it has simply to come somewhere over the lever *F*, and no accident whatever can happen even if the table stopped half an inch out of its proper place. In the class of machine wherein a pressing piston enters the mould, such irregularity would produce a complete smash-up.

In these machines the pressure usually adopted is about 12 cwt. per square inch on the surface of the briquette; this is found sufficient for all practical purposes. Some makers have said that this pressure is insufficient, and that to make a good briquette a pressure of two tons per square inch is necessary. This is contrary to the experience of the South Wales manufacturers, their experience being that the pressure used should be as light as is consistent with making a solid briquette, as any unnecessary pressure has the effect of crushing the coal in the process of compression and reducing it to a fine dust which requires more pitch for its combination and does not burn so freely as fuel composed of larger particles.

As stated above, for the purpose of making a good fuel the coal should not be ground too small. If it is required to make a briquette to look nice and catch the eye for domestic purposes, it

may be advisable to grind somewhat fine as it certainly makes a better looking briquette, but to make the best burning briquette, coal that passes through a mesh of between $\frac{3}{16}''$ and $\frac{4}{16}''$ is quite small enough. With regard to compression, it will be noticed that in the machine here described pressure is applied on one side only; some makers insist that it is necessary to compress on both sides in order to make a solid briquette. Now, double compression, as it is called, implies that a piston *must* enter the pressing mould, which, as stated above, is an arrangement which the writer strenuously opposes as a direct cause of accident.



THE FUEL PRESS.

While double compression is entirely right in theory, and to a very limited extent correct in practice, for all practical purposes the difference in the density between the pressed side of a briquette of ordinary proportions and the side furthest from compression is inappreciable, and the writer a few years ago produced sections of briquettes and placed them in the hands of an expert who was unable to say on which side they had been compressed. The great advantage in single compression as against the theoretical advantage of double compression, is, as stated above, that every mould can be arranged to carry a compressing piston with it, and the advantage thus gained in simplicity overweighs any advantage which can be gained in other ways.

The illustration on page 136 shows the form of pitch mill which the writer's firm, the Uskside Engineering Company, Ltd., of Newport, Mon., England, adopts for roughly grinding the pitch before it is conveyed to the distributor for measurement. The upper part of the mill is formed of coarse teeth, cast on a cast iron cone. The lower part consists of fine hard steel teeth which can be removed when worn and replaced. The degree of fineness to which the pitch is crushed can be regulated by a lever at the bottom. The object of this machine is not to grind the pitch fine, but simply to make the pieces sufficiently small to be easily capable of measurement, the actual grinding being done in the disintegrator.

The latter is of simple construction, consisting of revolving steel beaters within a casing. Around the lower part of the periphery are a series of gratings which regulate the degree of fineness of the crushed coal.

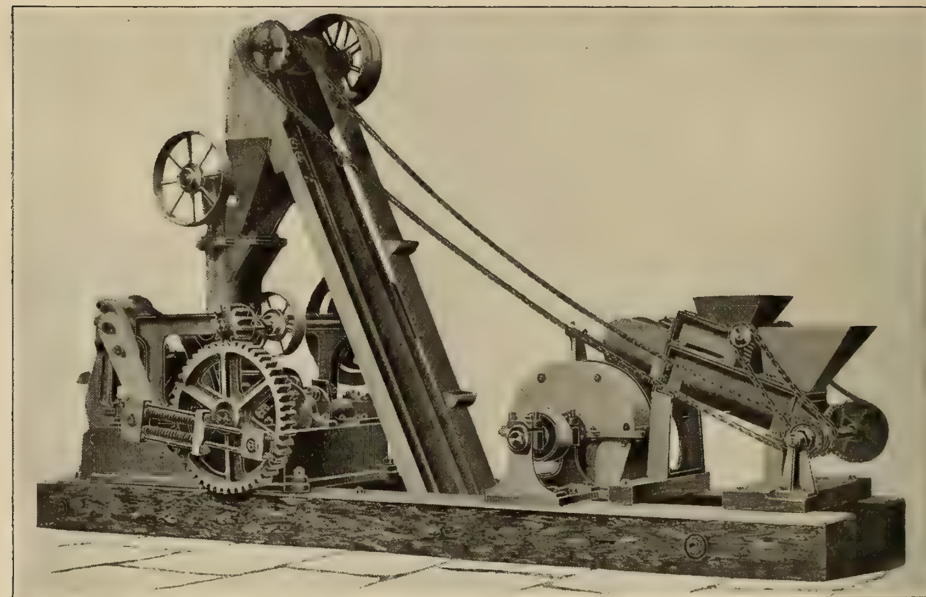
In many cases, however, these may be dispensed with altogether, as they sometimes choke, especially in the finer sizes, sufficiently fine grinding being done by the machine without the presence of any grating. These disintegrators are run at a moderate speed, as the higher speed necessary for the grinding of harder materials is unnecessary in the case of coal.

For the purpose of ascertaining the probable cost of manufacture, the following figures may be of interest. To arrive at the cost in any particular case, of course, the local value of coal and pitch must be taken into consideration, and also the local value of labour:—

Cost of Manufacture of 100 Tons of Patent Fuel per Day.

Labour Estimate :—			
One pressman at 5 shillings		5	0
Two lads taking off and loading on trolleys at 3 shillings		6	0
One man unloading coal at 4 shillings		4	0
One lad assisting at 3 shillings		3	0
One man at pitch mill		4	0
One man on first floor		4	0
One engine driver		5	0
One stoker		4	0
Two labourers at 3.6		7	0
Total	£2	2	0
Or 5.04d. per ton			

The cost of fuel would come out as follows, but, of course, you would have to substitute your values for coal, pitch,



MACHINERY FOR MAKING FUEL BRIQUETTES BUILT BY ROBERT MIDDLETON, LEEDS, ENGLAND.

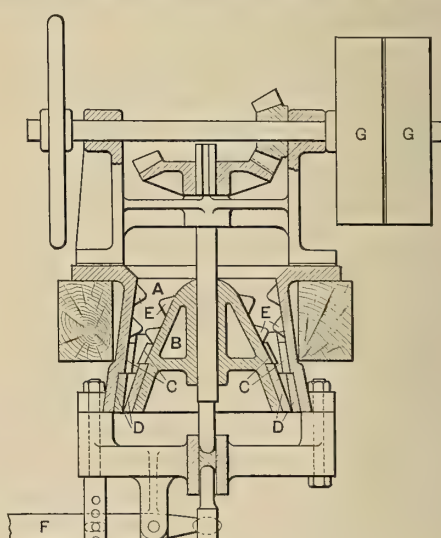
and labour for those shown in this estimate:—

Coal, say 92 tons, at 5 shillings	£23 0 0
Pitch " 8 " 32 "	12 16 0
Labour as above	2 2 0
Fuel burnt two tons at 10	1 0 0
Total	£38 18 0
	Or 7s. 10d. per ton

The only items omitted are depreciation and interest, which will be well covered by 2d. per ton, and management. In addition to the above estimate the writer gives below the actual cost of a year's working of a plant equipped by the Uskside Company, making 80 tons per day of 9 hours and using 2 presses, the briquettes weighing 4 pounds each. The labour in this case is relatively higher as each press requires attendance and turns out 40 tons.

	Cost per Ton.
Labour, including stacking (when necessary) average 12 months	d8.07
Management	0.00
Oil and grease	0.30
Sundry stores	0.50
Fuel, steam taken from colliery boilers, estimated at	2.00
	d10.87
Materials for briquettes:—	
Slack, 72 tons @ 4s. 10d	£17 8 0
Pitch, 8 " @ £1 6 3	10 10 0
Total	£27 18 7

This plant is working at the Chatterley Whitfield Colliery, Stoke-on-Trent, Staffordshire, and the above figures have been published by the manager, Mr. E. B. Wain. The coal there is somewhat dry and the pitch is iron



SECTION OF PITCH MILL.

works pitch of a low quality which accounts for the percentage. At the Usks-

side Company's works at Newport, which turn out from 200 to 400 tons per day, the percentage of pitch used, as shown by the annual accounts, works out under 8 per cent. The coal used is mostly from the Rhondda Valley.

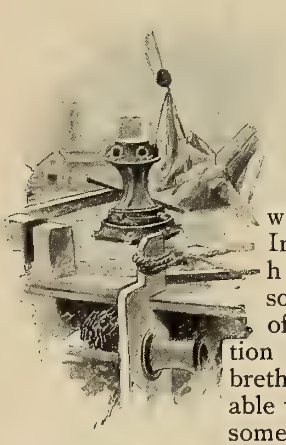
With regard to the cost ot maintenance the following facts may be of interest :—The repairs on the Chatterley Whitfield plant after working 3 years were almost nominal. The writer's firm have done all the repairs to the Newport 400-ton fuel plant, and during the first five years' work did not receive £70. Mr. James Clark, for whom we erected a 25-ton plant in 1889, said last year that "since it was erected it had cost about £25 in all for repairs."

Mr. Sadler, manager of Oldland Colliery, Bristol, in reply to an enquiry from the East Indian Railway Company as to the cost of maintenance of his 50-ton plant, stated that he had not spent five pounds after 3 years.

In hot climates a great difficulty sometimes occurs in procuring pitch. It is not always possible to obtain it locally, and if the pitch is exported from England the cost will be, sometimes, prohibitory; besides, pitch is not an easy material to use in a very hot climate. Efforts have been made for many years to find a substitute for it, but nothing has been really successful except under very special circumstances. We have experimented largely with a patent process of mixing a certain proportion of lime and meal, and using this in the place of pitch. This process is easily worked, and in a hot climate is very cheap. Of course, it must not be supposed for a moment that the briquettes are equal in value to those made of pitch, but where small coal has to be thrown away, and where the briquettes can be used with a strong draught they have proved successful. The best way to burn them, is to use them half and half with large coal and not alone. A short time ago we made an experiment with one of our 50-ton plants and turned out a quantity of very good fuel.

SOME INTERESTING APPLICATIONS OF HYDRAULIC POWER.

By George W. Dickie.



WHAT I have to say on some applications of hydraulic power to various appliances in use at the works of the Union Iron Works Company, has been prepared solely for the purpose of giving such information to my professional brethren as I have been able to acquire through a somewhat extensive experience with hydraulic work, some of which has been of unusual character both as to conditions under which the work was carried out and the magnitude of the work itself.

I have decided to write this article in the first person, because it will enable me to get close to my subject. In all kinds of hydraulic work, if you are to win success you must not only be the first person there, but the last person there also. And it will enable me to get closer to my readers, and thus be able to say some things directly instead of leaving them to be inferred.

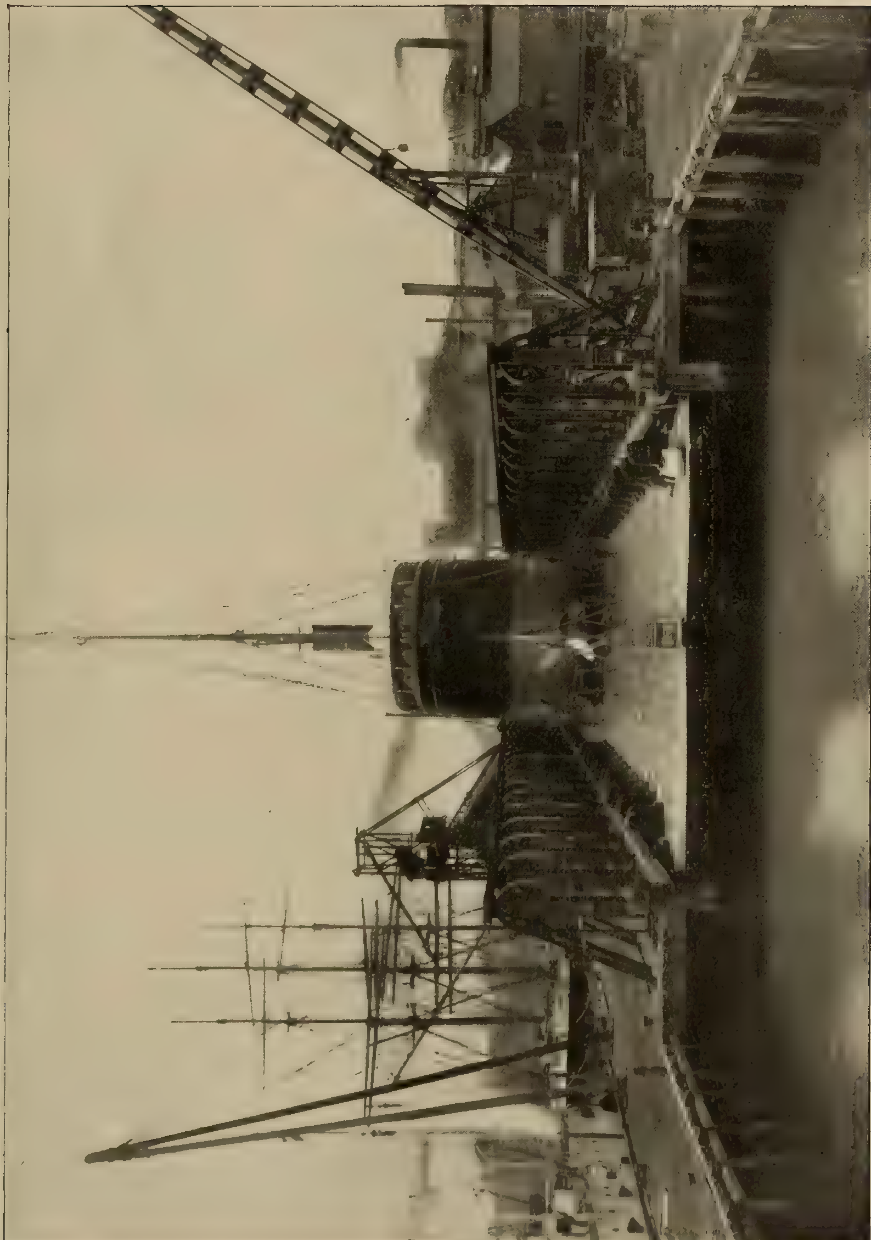
The use of water under a high pressure, imparted to it either from the fact of its source being at a high elevation as compared with the level where it is used, or by power derived from any other source, applied through some kind of pumping mechanism, in some respects, is the most simple and effective agent for transmitting power, and the most easily applied, where the application can be direct, for a great many of the purposes for which great concentrated power under absolute control is required. I have a conviction, based upon my own experience, that water under high pressure, as an agent for the transmission of power has latent possibilities yet to be developed, that will bring it into a more extended application as these possibilities become better understood.

It has not the capacity to produce the brilliant effects that are so readily obtained from electric power transmissions, but as a steady, faithful and reliable servant, it outranks, in my opinion, any of the newer agents for the transmission of power, when applied to any of the varied purposes that favor the conditions under which water must always be used, and, I am confident, that the field in engineering for the application of hydraulic power will become wider and more productive as engineers become better acquainted with the possibilities of its cultivation.

In this article I propose to deal only with water under pressure imparted to it by hydraulic pumps; in other words, the water, so far as our present inquiry is concerned, is simply an agent of transmission, and not a prime mover.

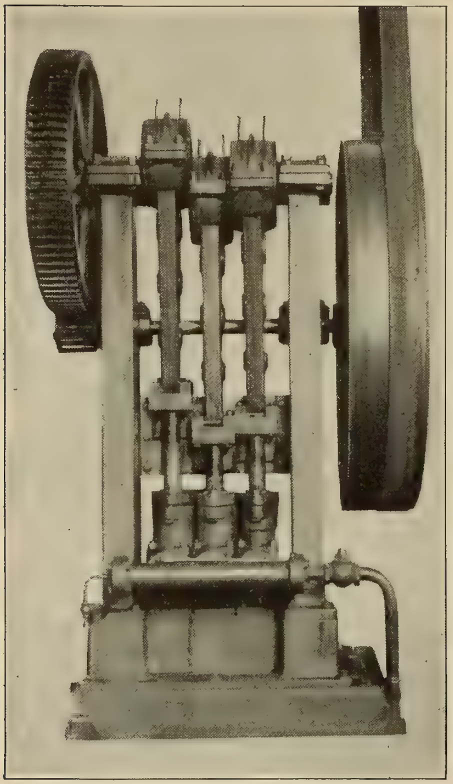
The natural starting point is, therefore, the means by which the pressure is imparted to the water, giving it the strength to serve us, and perform the functions for which we desire to use it. The pumps being the source of power, their efficiency will always be a prominent factor in the success or failure of any application of a hydraulic system of transmission.

For the permanent source of power for a hydraulic plant I would never think of using ordinary, direct steam pumps, even if the steam cylinders are



AN END VIEW OF THE HYDRAULIC DOCK AT THE UNION IRON WORKS, AT SAN FRANCISCO, WITH A STEAMER ON THE PLATFORM.

compound. The simplest form of pump, and the most effective, is a three-throw crank shaft operating three single-acting plunger pumps, with the pump valve area sufficiently large to admit of about 160 feet per minute speed of plunger, with not more than two and one-half per cent. more pressure in the pump barrel than that in the accumulator. From 1200 to 1500 pounds per square inch is, in my experience, the best pressure to use for general purposes. It suits the ordinary extra strong, lap-welded pipe in the market. Hemp packing will give no trouble in stuffing boxes at that pressure. Ordinary fairly sound castings of brass or iron will stand the pressure indefinitely. At pressures much higher than that stated, castings, unless of steel, and these are hard to get sound, begin to fail on the inner surface by developing small cracks that gradually deepen until they reach a point where the solid metal outside of them will not sustain the load. In cast iron or brass more than three or four inches thick, the outer portion of the metal does not appear to take its proportion of the load, and destruction works from the inside outward.

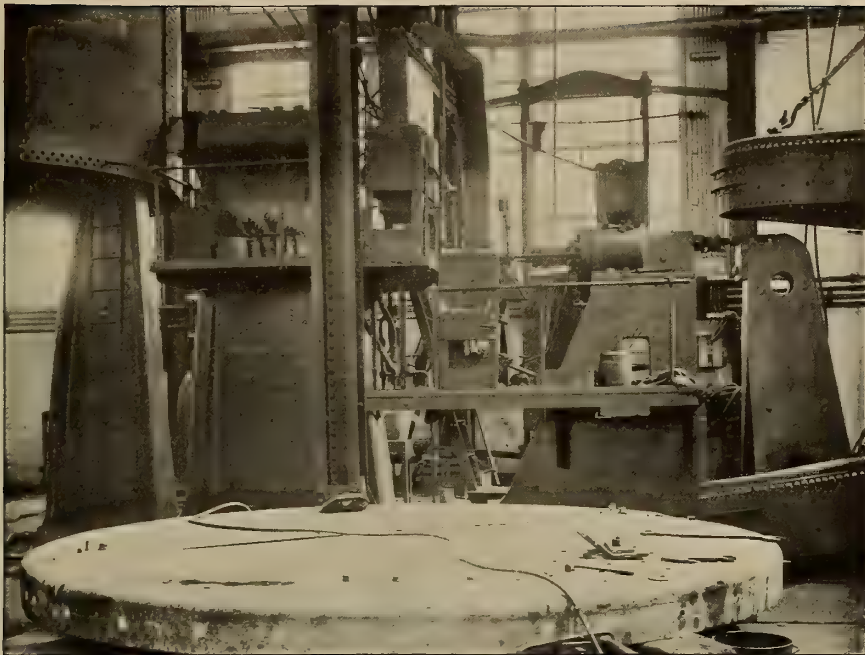


ONE OF THE PUMP SETS FOR THE HYDRAULIC MAINS.

If engines are to be used to drive the pumps, I would gear them six or eight to one, using compound or triple expansion engines, according to the steam pressure used in the works. The engines should be under the control of a first-class shaft governor, and should always run at the same speed. The accumulator, when full, should open a valve on the pump discharge, passing the water to the suction side. Between this valve and the accumulator there would be a check valve. The load would be thus taken entirely off the pumps, while the engines would be going at the regular speed without load, ready for work the instant it was required.

At the Union Iron Works in San Francisco, the hydraulic plant was at first small and the pumps were designed to be driven by a belt, the belt pulley being in the same relationship to the pumps as the engine above mentioned. The plungers are four inches in diameter, and of eight inches stroke. Six sets are now in operation. Each set of pumps is provided with an automatic belt shifter, which consists of a steel rod on which the fork for shifting the belt is fastened. Each end of the rod enters a small cylinder, forming a ram. The pressure is admitted to one cylinder, and released from the other when the accumulator is up, thus driving the rod with the belt shifter to one end and the belt to the loose pulley. The reverse occurs when the accumulator begins to descend and the pumps start up. This is a good arrangement for belt-driven pumps, and has never failed in thirteen years of steady operation at the Union Works.

The accumulators at these works are all of the weighted ram type, the main accumulator being near to the main

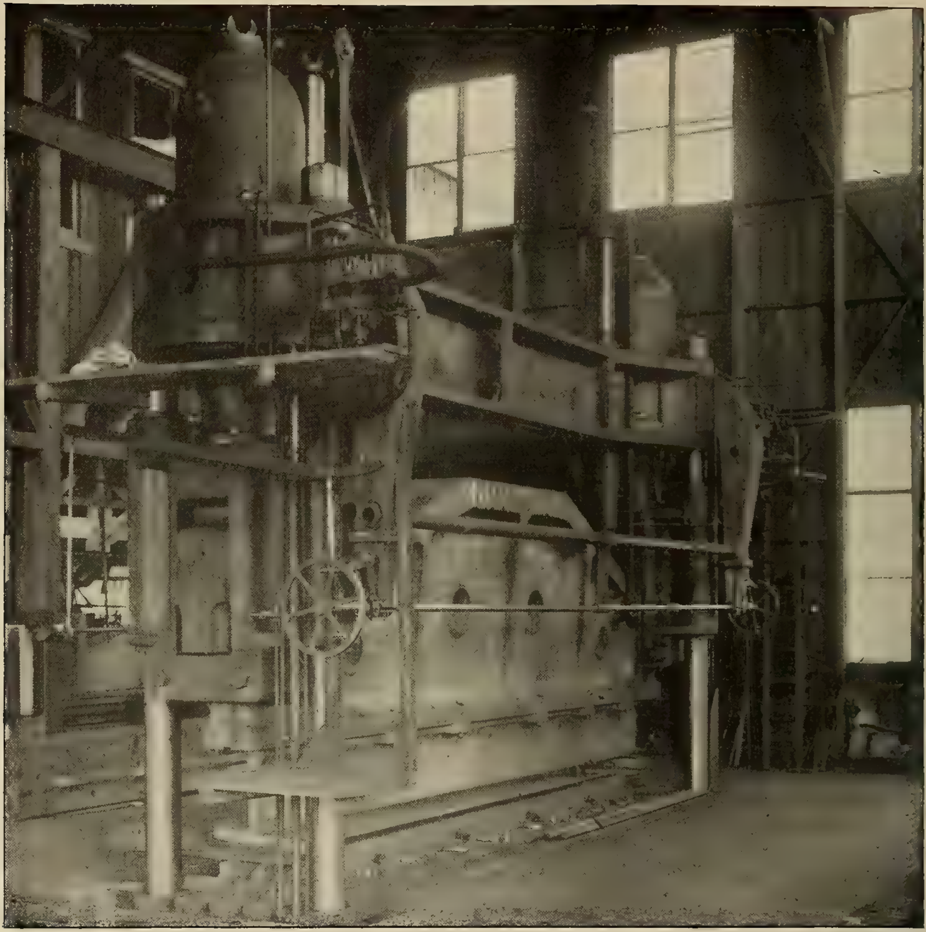


HYDRAULIC RIVETING MACHINES IN THE BOILER SHOPS OF THE UNION IRON WORKS, SAN FRANCISCO.

group of pumps. This accumulator has a 12-inch ram and 12 feet traverse. The weight is, therefore, 135,500 pounds for a pressure of 1200 pounds. Besides the main accumulator there are two smaller ones,—one in the boiler shop and one in the shipyard, close to where the large hydraulic machines are placed. These have 8-inch rams, and 8 feet traverse. The load on the ram is less per inch of area than that of the main accumulator by about 30 pounds. The consequence is that they are always at the top, unless a sudden demand by the machines close to them reduces the pressure in the main pipes more than the difference, in which case a portion of the work will be done by the water stored in the smaller accumulators. When the demand stops, the water still continues moving in the pipes until the small accumulators are again at the limit of their traverse. There is another type of accumulator in use in connection with the hydraulic dry dock at the Union Iron Works providing for a change in pressure as the load increases, which will be described in connection with the dock pumps.

Dead-weight accumulators, while having the advantage of an even pressure through the range of their movement, have the disadvantage, especially where the system is extended and some operations, such as heavy riveting and plate-bending, require great power suddenly, and for short intervals of time, of producing heavy shocks on pipe lines, cylinders and all parts open to the pressure side of the system. For instance, a quick movement of the plate-bending press is required, say, 12 inches in five seconds, and the machine has two 12-inch rams. The 135,500-pound weight of the main accumulator would fall about three feet in the five seconds, and be suddenly brought to rest when the valve closes, causing a shock throughout the whole system. Spring-loaded rams have been used to reduce this shock, but the inertia of such rams prevent them from giving anything but a partial relief.

I have been long in favour of air-



COLD BENDING PRESS IN THE SHIPYARD.

loaded accumulators for hydraulic systems of power transmission. Twenty years ago I had a splendid opportunity to test this type of accumulator, in the efforts to drain the deep workings of the Comstock mines at Virginia City, in Nevada. I was entrusted with planning and carrying out a great hydraulic pumping system for the combination shaft of the Chollar, Norcross and Savage mines. It is not my purpose to describe anything of this great hydraulic plant, except the accumulator.

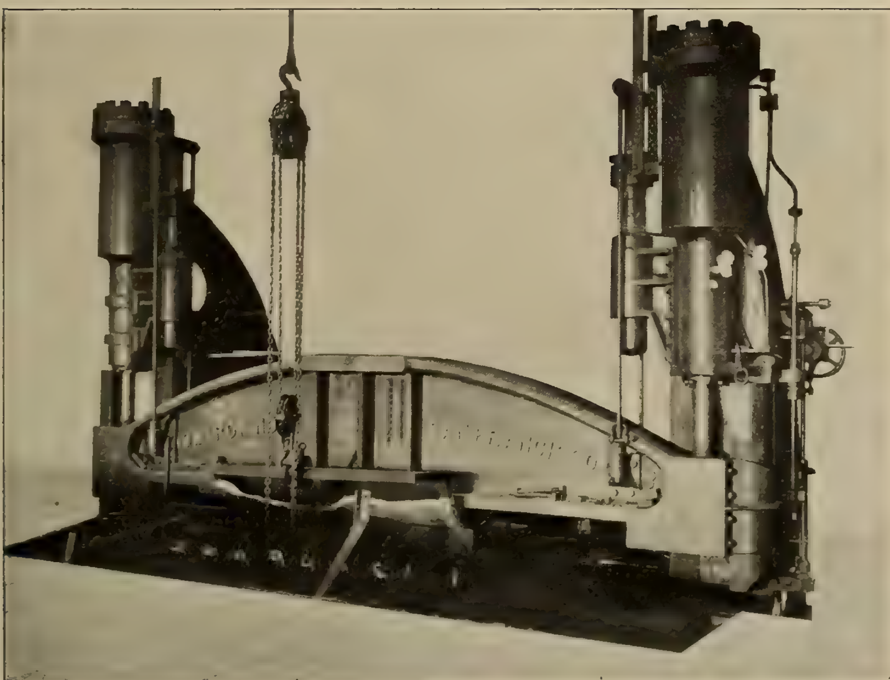
The surface pumps for generating the power were double-acting plunger pumps, with 8-inch rams and 12-foot stroke; so an accumulator of some capacity was required. This consisted of a stand-pipe of cast iron, 5 inches thick and 86 feet high, the internal diameter being 36 inches. The normal pressure carried was 1000 pounds per square inch, and the normal level of the water in the accumulator was 12 feet from the top of the outlet pipe. A small compound air compressor was used, when necessary, to replenish any loss of air pressure. This, however, was so small that a few hours' work of the compressor each week was all that was necessary. This was, I believe, the first air compressor built on the principle, now so common, of compressing in two stages.

It was intended to have a range for the accumulator of about 8 feet, the

pressure ranging from 50 pounds above to 50 pounds below normal. It was found, however, that this amount was more than was required, the range never exceeding four feet. With a range of ten feet, which would give a range of pressure very much less than with the dead-weight system, this would equal a ram of, say, 18 inches diameter and 40 feet traverse, with a weight of about 300,000 pounds for our pressure of 1200 pounds per square inch. A sudden demand that would drop the weight two or three feet, followed by as sudden a stoppage, would produce shocks that would be very difficult to provide for. The plan that I advocate, therefore, of simply introducing above the accumulated water an atmosphere which is dense enough to produce the pressure, and sufficient to admit of a considerable range in the quality of the water stored, without too great a range in pressure, at once dispels the difficulty attending weighted rams.

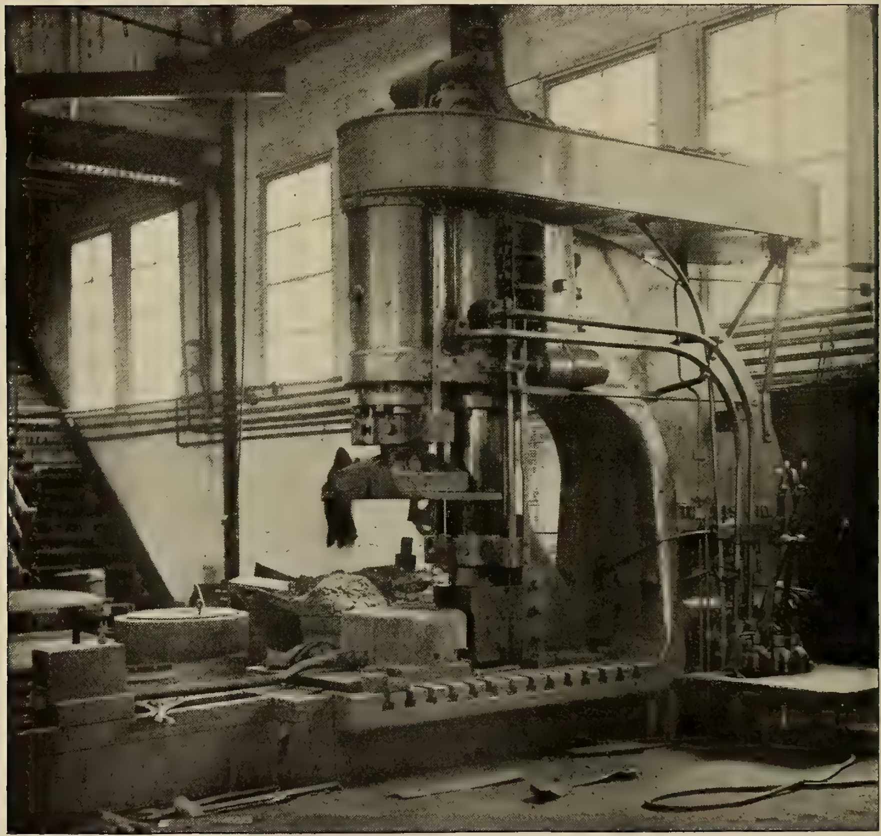
Such an accumulator need not be arranged as one column, although that is the simpler form. The water space alone need be vertical; the air space may be arranged in tubes alongside the water column, or in horizontal form, as convenience may require. There should be an automatic valve at the base of the accumulator to prevent air from getting into the pipe system in case water should at any time get exhausted entirely from the accumulator.

I will now endeavour to describe some of the appliances at the Union Iron Works by which this water pressure is converted into useful work. One very simple appliance is that for opening doors. There are quite a number of large doors in the erecting shop, machine shop, foundry and boiler shops, that could not very well be hinged, and are consequently fitted in vertical slides, either of wood or channel steel. The doors are generally 25 feet wide, and 25 feet high. Behind the guide on each



ANOTHER HYDRAULIC COLD BENDING PRESS.

side there is a 3-inch pipe, with a stuffing box and a gland at the upper end, fitted to receive a 2½-inch ram. This ram is a plain steel bar, 26 feet long, the upper end abutting against a bracket bolted to the upper part of the door. One small valve admits the water into both vertical pipes, giving an upward lift of about 4800 pounds on each side. As the doors weigh about 6000 pounds, the pressure lifts them gracefully to whatever height is required. Another small valve exhausts the water and lowers the door. Oven doors in the foundry are handled in the same manner.

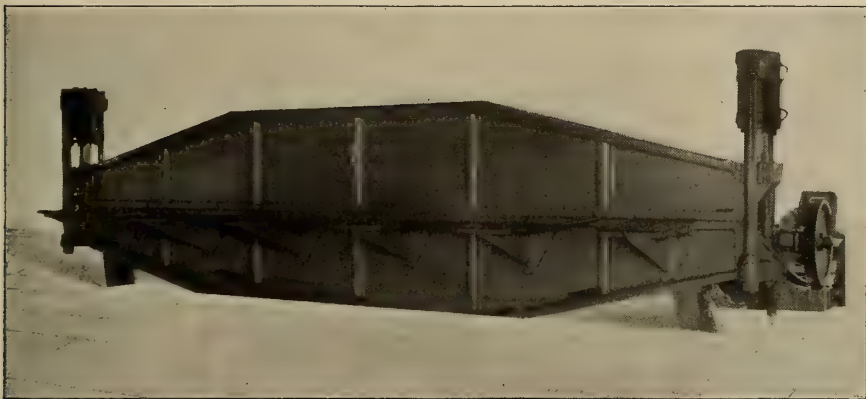


A FLANGING PRESS FOR HOT WORK.

Quite a large number of hydraulic wall and post cranes are in use throughout the works. These are of very simple construction. A cast iron cylinder is bolted to a column or to the wall, long enough usually for a lift of ten feet. Most of the cranes have rams 4 inches in diameter, which would equal a lift of four tons. Above the cylinder a long guide is bolted to the column or wall. The sliding piece that works in the guide is usually from one-third to one-half the length of the jib, say, about 8 feet for a 20-foot jib. The jib is hinged to the lower end of the sliding piece, the suspension rod being hinged to the upper rod of the sliding piece, and attached to the outer end of the jib. The jib is an I-beam with a trolley that traverses its whole length. This makes a complete crane having only six pieces, —the cylinder, the ram, the slide, the jib, the suspension rod and the trolley.

In another and more recent form of wall crane the ram does not raise the

jib, but passes through an eye in the centre piece that carries the jib and around which it swings. On top of the ram is a single chain sheave over which the lifting chain passes, its end being secured to the inner end of the jib. A fixed sheave on the jib immediately outside of the ram, under which the chain passes, transfers the power of the ram over the moving trolley to the crane hook, as shown in the illustration on page 146, which shows this type of crane as used in the new erecting shop. Another of the same kind is shown beyond the one just described, while further up, towards the end of the shop, there is another of the type first described where the jib is lifted direct by the ram.

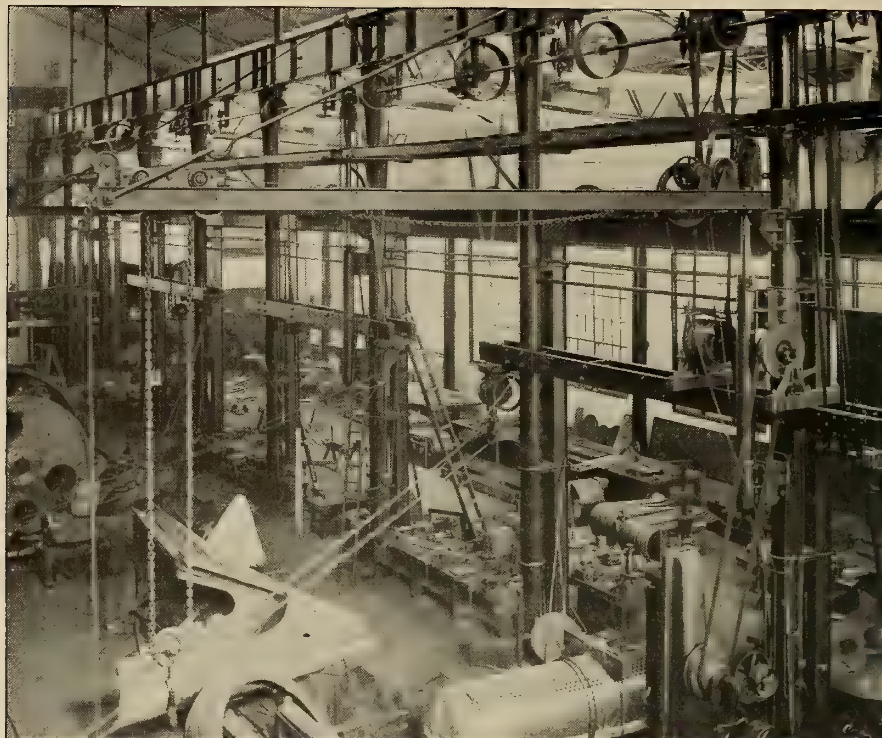


HYDRAULIC CLAMP ON A PLATE PLANING MACHINE.

In the boiler shop the principal hydraulic machines are the riveters. The illustration on page 141 shows two large ones for marine boiler work. Either of them will drive a 1½-inch rivet. One takes 12 feet, the other 8 feet from the edge of the plate to the centre of the rivet. Over each riveter is a 30-ton crane, each working independently of the other, and so placed that the main traveling cranes of the shop will pass over them. There are also small hydraulic riveters for small boiler work, and pipe work, with hydraulic cranes to serve them, and vertical and horizontal punching machines.

For the flanging of boiler work where definite shapes are repeated in corresponding parts, the Tweddell machine is used, and is very efficient for that class of work. In the shipyard, however, where plates have to be shaped to conform with ever-changing sections, and where the best work and fairest lines are obtained when the work is done cold, a beam press has been found the best suited to the work. In this case, absolute control of very small movements is absolutely necessary, and a thorough knowledge of the nature of the machine and the material to be manipulated is necessary to the man who is to work such a machine.

Before dealing with the work of such a machine, it will be well to describe the machine itself. I designed the first beam press for the Union Iron Works fourteen years ago. This machine is shown on page 143, bending one of the armoured sponsons for the 6-pounder guns of the United States cruiser *Olympia*. The machine takes in 15 feet between the end frames, has a vertical movement of three feet, and exerts a pressure of 200 tons. The pressure rams are 14 inches diameter, and the pull-back rams are 5 inches. The valves are operated through a floating lever which permits of perfect control as to the speed and extent of movement. Definite formers are seldom used on this machine; several beams, with the bending edge at various angles, are about all that is required to shape plates



HYDRAULIC WALL OR POST CRANES IN THE ERECTING SHOP.

to almost any form. A much larger machine of the same class has just been completed and put into service at the shipyard, and is shown on page 142. This takes in 22 feet 6 inches between the end columns, has a vertical movement of 4 feet, 5 inches, and exerts a pressure of 500 tons. The pressure rams are 21 inches in diameter, and the pull-back rams 7½ inches. The lower beam of this machine, which, being below the floor line, does not appear in the picture, weighs 60 tons, and the upper or moving beam, 40 tons.

The movements of this machine are, as in the smaller one, controlled by a floating lever with the addition of an automatic flooding arrangement, which is so designed that in bringing the beam down to the work the pressure on the pull-back ram keeps a large valve open from the main cylinders to a water tank above, so that, whether the beam is raised or lowered by the valve of the pull-back rams, the water flows freely out of, or into, the large ram cylinders; but when the beam rests upon the work and the pressure is no longer under the pull back rams, the valve between the main cylinders and tank closes, and if the differential gear keeps moving, the pressure valve opens on the main cylinders, and the power of the machine is applied to the work. This is a great saving of pressure water, as it is never used in the main cylinders to bring the beam to its work, but only for the actual work to be done. I expect that this machine will prove to be of great value in bending heavy plates into the many irregular forms required for protective deck work, sponsons, etc.

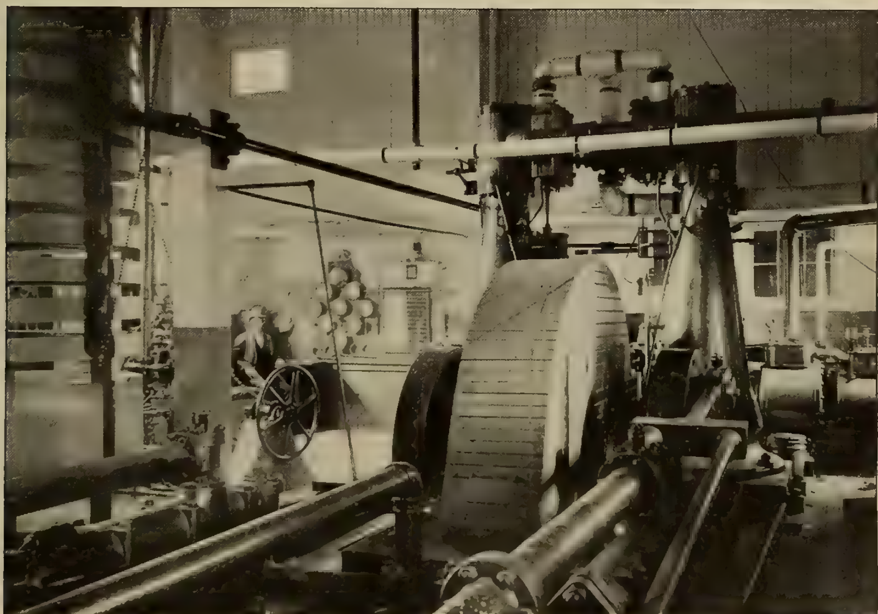
Hydraulic clamps for plate planing machines represent a very simple and effective application of water pressure, that is nowhere used so far as I know, except at these works. I designed the first plate planer with a hydraulic clamp for the Union Iron Works fourteen years ago, and there are now five large

plate planers with this clamp in use at the works, taking plates 25 feet long.

Having thus briefly described some of the more important and novel applications of hydraulic power to the various tools that perform functions favourable to this method of power transmission, the largest hydraulic machine and the only one of its kind, so far as I know, remains to be described,—the hydraulic dock at the Union Iron Works.

To the modern shipbuilding and engineering establishment a dry dock is quite as necessary as any other tool in the building of ships and engines. With not been very encouraging, and the necessity for docking and cleaning iron and steel ships at regular intervals confronts the ship owner as much to-day as it ever has done.

This necessity for docking every six or nine months, against which inventors have laboured so hard, is one of those natural conditions that sometimes forces the selfish man into doing what is right. The periodical inspection of a ship's bottom, forced upon her owner by the persistent and rapid growth of marine life in spite of all his pains, is a great natural safeguard which seems to be



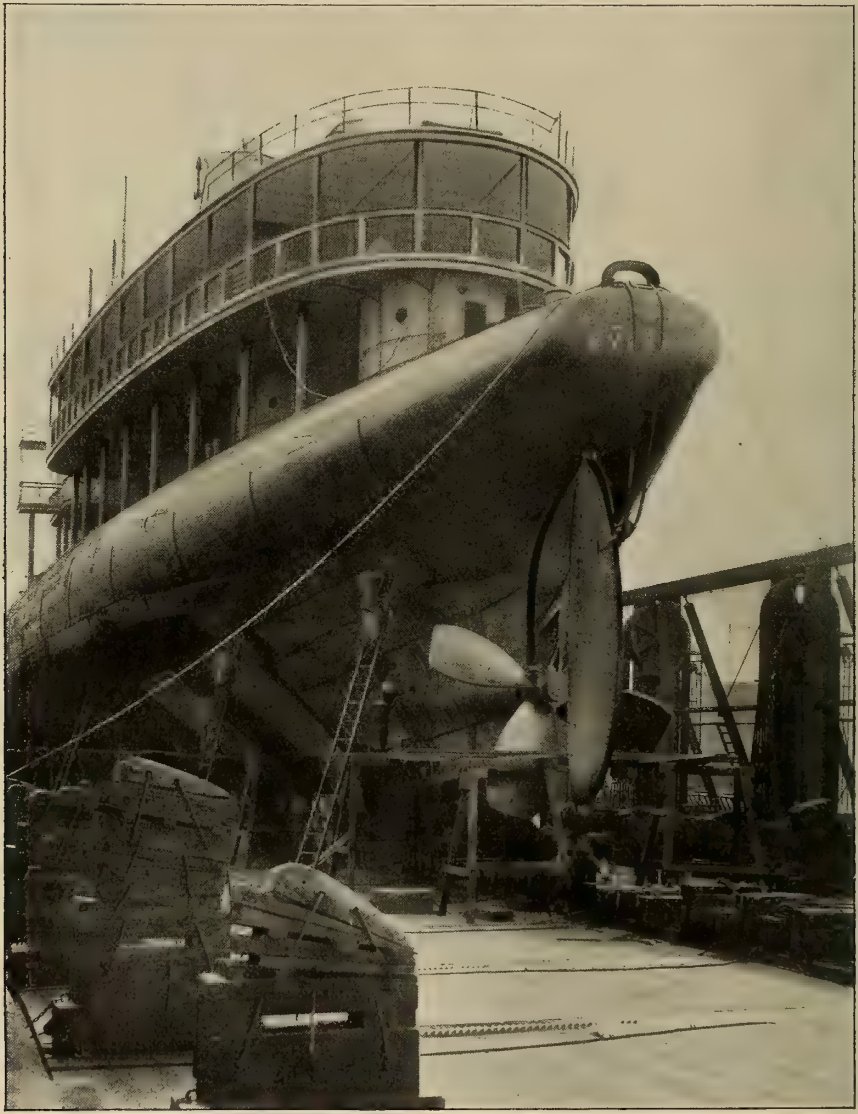
INTERIOR OF PUMP HOUSE AT THE HYDRAULIC DOCK. ON THE LEFT IS SHOWN THE METHOD OF TAKING ON THE LOAD BY THE ACCUMULATOR RAM.

the advent of iron and steel as a material for building ships came the question of how to prevent the under-water portion of the hull from fouling, and thus retarding the speed of the vessel.

Inventors and chemists have spent much time and labour in attempts to produce a coating or paint that would be fatal to marine animal and vegetable life, and at the same time preserve the iron or steel of the hull. The success attending their efforts have, however, provided for those who "go down to the sea in ships and do business in the great waters", against the neglect of those responsible for the safety of him or his property. It also helps the business of the shipbuilder, for while the rascally teredo eats up our wharf supports, giving us no end of trouble and expense, his little brothers and sisters attach themselves to the iron or steel skin of the ship, retarding her progress, so that the lost time and big coal bills

force her owner to patronise the dry dock, bringing us the wherewithal to buy food for our ever hungry teredo.

When the Union Iron Works some fourteen years ago moved from their old location in the heart of the city of San Francisco to the present location on Mission Bay, the object was to be in a position to take advantage of the increasing steamship trade of the port, and provide facilities for carrying on a large business, the principal item of which should be marine engineering and shipbuilding. Chief amongst the many requirements of such an establishment is a dry dock.



AN END VIEW OF A DOCKED WHALEBACK STEAMER.

Various forms of dry docks were considered in deciding what would be best adapted to the conditions of the business, and the nature of the ground upon

SIDE VIEW OF THE DOCK WITH A STEAMSHIP ON THE PLATFORM.

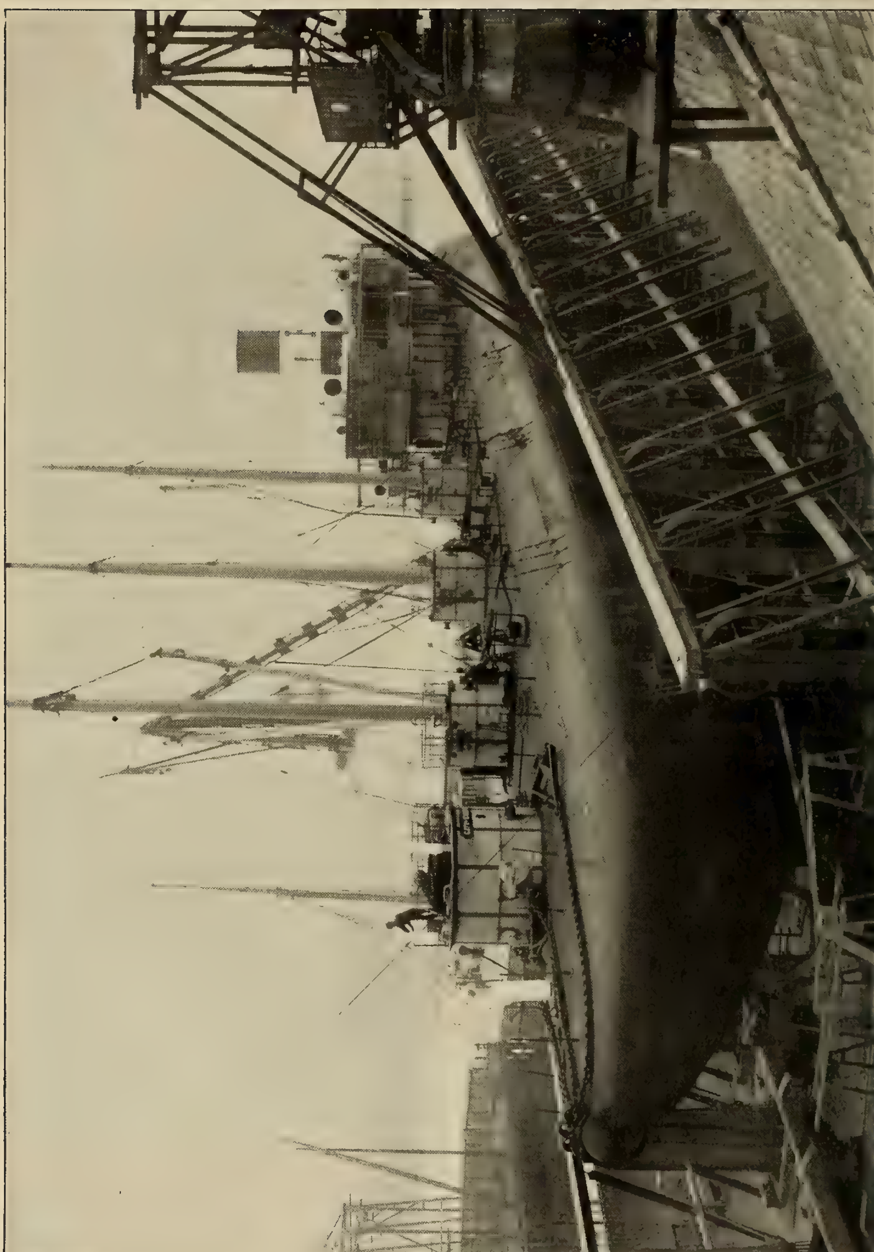
which the dock would be built. A large proportion of the docking business of San Francisco is for cleaning and painting, and most ships are on the dock for only one or two days, and for that reason the getting of the dock itself and the ship dry in the shortest possible time, is a matter of first importance.

The site available for a dock at the Union Iron Works was a mud flat. The depth of soft mud being from 80 to 90 feet, would render the working of a graving dock very disagreeable, as such docks, where much mud is carried in with the water, require a long time to be cleaned and to dry out. I had prepared plans for a hydraulic dock, including an automatic control, which, I felt confident, would meet all the requirements of the situation, and which, after careful consideration, the Union Iron Works decided to build. Work was begun in January of 1886, and the dock was opened for business on June 15, 1887.

This dock, as will be seen by the illustrations on pages 139, 148, 149 and 150, consists of a platform built of cross and longitudinal steel girders, 62 feet wide and 440 feet long, having keel blocks and sliding bilge blocks upon which the ship to be lifted rests. The lifting power is obtained from a set of four single-acting horizontal plunger pumps, the diameter of the plungers being 3½ inches, and the stroke 36 inches. Forty double strokes per minute are the regular speed. These pumps are operated by a pair of vertical engines, the cylinders being 12 inches diameter and 16 inches stroke, and geared five to one on the pump shaft.

There is a weighted accumulator, or regulator, connected with the pumps, the throttle valve of the engines being controlled by the movement of the accumulator. The load on the accumulator consists of a number of flat discs of metal, the first one about 14 inches thick, and the others about 4 inches thick, the diameter being about 4 feet. The first disc gives a pressure of 300 pounds per square inch. This is sufficient to lift the dock platform without a ship, and is always kept on.

In lifting a ship as she comes out of the water and gets heavier on the platform, additional discs are taken on by



A WHALEBACK STEAMER IN THE UNION IRON WORKS HYDRAULIC DRY DOCK.

the accumulator ram as required. These discs are suspended by pins on the side catching into links of a chain. The engineer, to take on another disc, unhooks the throttle from the accumulator rod, speeds the engine a little above the normal speed, the accumulator rises and takes the weight of the disc to be added; the link carrying that disc is thus relieved and is withdrawn. The engineer again hooks the accumulator rod to the throttle and the whole is self-acting again until another weight is required. When all the discs are on the ram, the full pressure of 1100 pounds is reached, which enables a ship of 4000 tons weight to be raised.

There are eighteen hydraulic rams on each side of the dock. These rams are each 30 inches in diameter and have a traverse of 16 feet, and as the platform rises two feet for one foot movement of the rams, the total vertical movement of the platform is 32 feet. When lowered to the lowest limit, there are 22 feet of water over the keel blocks at high tide.

The foundations consist of 72 cylinders of iron, which extend from the top girders to several feet below the mud line. These cylinders are driven full of piles, no pile being shorter than 90 feet. The iron cylinders are to protect the piles from the teredo, which is very destructive in San Francisco harbour. A heavy cast iron cap completes each of the foundation piers, and two heavy steel girders extend the full length of the dock on each side, resting on the foundation piers and uniting them all longitudinally. The hydraulic cylinders are carried on these girders by large castings resting on the girders, each having a central opening to receive a cylinder, which passes down through the girders between the foundation piers. There are 36 foundation piers and 18 hydraulic cylinders on each side of the dock.

On top of each hydraulic ram is a heavy sheave, or pulley, 6 feet in diameter, over which pass eight steel cables, two inches in diameter, making, in all, 288 cables. One end of each cable is anchored in the bed plates supporting the hydraulic cylinders, while the other end is secured to the side girders of the platform. Each of the cables has been tested with a load of 80 tons, so that the total test load for the ropes has been 21,000 tons.

In lifting a ship, the load is never evenly distributed on the platform. There is, in fact, often more than one ship on the platform at once. Some rams, therefore, may have a full load, and others much less. Under these conditions, to keep the platform a true plane, irrespective of the irregular distribution of the load, I designed a special valve gear to make the action of the dock perfectly automatic. Down each side of the dock a shaft is carried, operated by a special engine in the power house. At each hydraulic ram this shaft carries a worm, gearing with a worm wheel on a vertical screw extending the full height reached by the traverse of the ram. This screw works in a nut on the end of a differential lever. The latter operates the inlet and outlet valves of the hydraulic rams. The valve box is secured on the ram itself and moves up and down with it. The inlet and outlet pipes slide in stuffing boxes.

To lift the dock, the engine operating the valve shaft is started and with it the operating screws. These, through the levers open the inlet valves. The rams now begin to move up; if any one has a light load it will move up ahead of the others, but in doing so, it lifts the other end of the lever and closes its inlet valve. In fact, the screws are continually opening the valves, while the motion of the rams is continually closing them, so that no ram can move ahead of its screw, and the speed of the screw determines the rate movement of the lifting platform.

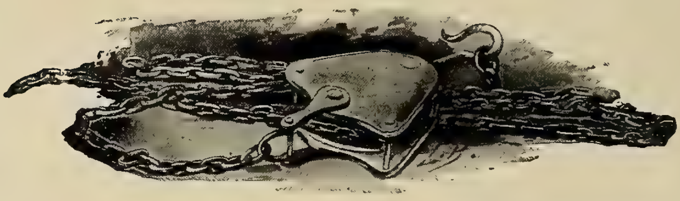
To lower the dock, the engine operating the valve shaft is reversed, and the screws and levers then control the outlet valves as they controlled the inlet valves in raising. When the platform has reached the limit of its movement, a line of locks on top of the foundation girders, 36 on each side, are pushed under the platform by a hy-

draulic cylinder and the platform is lowered on to them, where it rests until the work is done on the ship; then the platform is again lifted, the locks are drawn back, and the platform, with its load, is lowered until the ship floats out. All the operations are automatic.

Since the dock was opened 1287 ships have been lifted in it without any accident whatever, the total register tonnage being 1,414,154. The great favour in which the dock is held by ship owners and captains is partly due to the fact already mentioned, that the ship is lifted above the level of the tide water, where the air can circulate freely under the bottom, thus quickly taking up all the moisture, and where the workmen can carry on operations in greater comfort.

Where extensive repairs have to be undertaken on iron or steel vessels, the fact that this dock forms part of an extensive shipbuilding plant, and is located right in the yard, enables such repairs to be executed with dispatch and economy. Several large steamships have had the under-water portions of their hulls practically rebuilt in this dock. The steamship *Columbia* of the Oregon Line had practically a new bottom, including the whole of the keel, completed in twenty-six days. This is possible because every facility is alongside the dock, and the bottom of the vessel is on a level with the yard.

This being the only hydraulic dock controlled automatically, it has attracted a large amount of attention from engineering experts in this class of work. English, French, German and Russian engineers have visited the Union Iron Works to study its working, and their reports have done much to bring the facilities offered to shipping for repairs by the Union Iron Works to the notice of ship owners the world over.



THE AMERICAN SYSTEM OF ROPE TRANSMISSION.

By R. D. O. Smith.

THE modern systems of power transmission for mechanical uses, by means of ropes, is commonly accredited to the Swiss engineer C. F. Hirn, at Logelbach on the Rhine, about 1852; but ropes and round belts had been used for the transmission of power on a smaller scale, and the transmission of power over long distances in various systems of haulage was common, long before that. The idea which originated with Hirn was not that a round belt could be substituted for a flat belt, but that by converting the motive power into the highest practicable velocity of the transmitting tension organ, size and weight of that organ might be reduced to practicable dimensions and its length extended indefinitely, its velocity being reconverted into power at the operative point.

To illustrate, it may be said that prior to that time in all power transmissions by what Reuleaux calls tension organs, the velocity of the driver had always been only the velocity which would conveniently balance the desired velocity of the driven, and the tension organ communicated velocity directly to the driven; while in the Hirn system the tension organ was driven at the highest practicable velocity, irrespective of the desired speed of the driven machinery.

The difference in effect may be more clearly illustrated if it is considered that if a certain machine requires 1 H. P. to drive it under the old system, the tension organ must be capable of transmitting directly 1 H. P. at the speed of the machine; but a tension organ of one-half that size, moving at double the machine speed, will also transmit the required H. P.; the significance of the change in its application to large power and long distances will be at once apparent. This was the simple essence of an invention which opened a new epoch in the transmission of power.

The telodynamic cable of Hirn (Fig. 1) proved to be a great success, but brought with it many difficult, though subsidiary, problems which required solution before that success could be assured, and, simple as these problems now appear, eight or ten years were consumed in overcoming them.

The adaptability of ropes to do the work of belts, without the limitations of belts, was soon recognised. In England they soon began to be applied for main drives as substitutes for very heavy, long and expensive belts, and the most obvious method was adopted, viz., the multiplication of single rope belts running in grooved wheels, to acquire in the aggregate the requisite carrying power (Fig. 2). But the aggregation of single rope belts carries with it limitations which confine its usefulness within comparatively narrow bounds. It is impracticable to secure uniform length for several independent rope belts, because it is impossible to regulate or limit the amount of stretch of each one. It

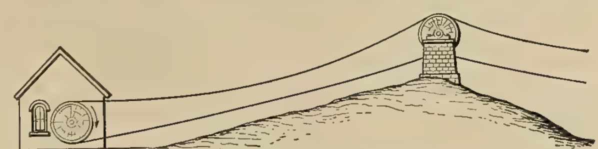


FIG. 1. HIRN'S TELODYNAMIC CABLE.

is also impracticable to apply tensions devices separately to a number of rope belts running side by side, close together, and it is useless to apply such a device, common to all the several ropes.

Hence, it became necessary that the rope should be heavy to insure proper pressure and adhesion to the wheels by its own gravity. To accomplish that end with uniformity as to the driving and driven wheels, it becomes necessary that driving and driven shafts shall be both horizontal, not far from the same level, and at a considerable distance apart. Under these favourable conditions the English system is efficient and economical, but the limitations prevent its application in any place where such favourable conditions are not attainable.

This, in brief, was the condition of power transmission by ropes in 1885 when Wallace H. Dodge, in America, proposed to employ a single endless rope in multiple wraps, and to apply thereto a proper tension device, thus at one stroke eliminating the limitations of the Swiss and English systems, and making the rope universally applicable for all power transmission purposes, regardless of distance and direction.

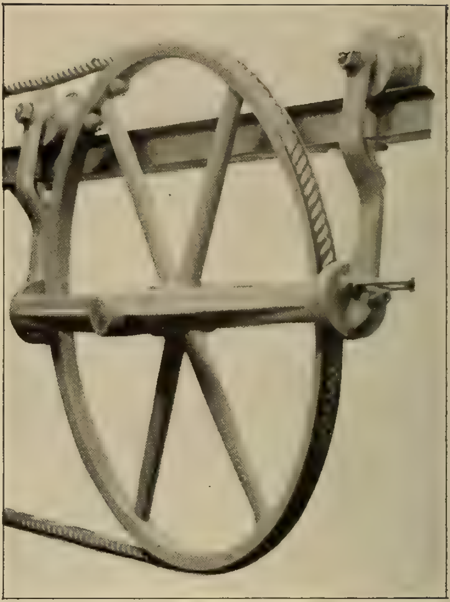


FIG. 3. A TENSION CARRIAGE.

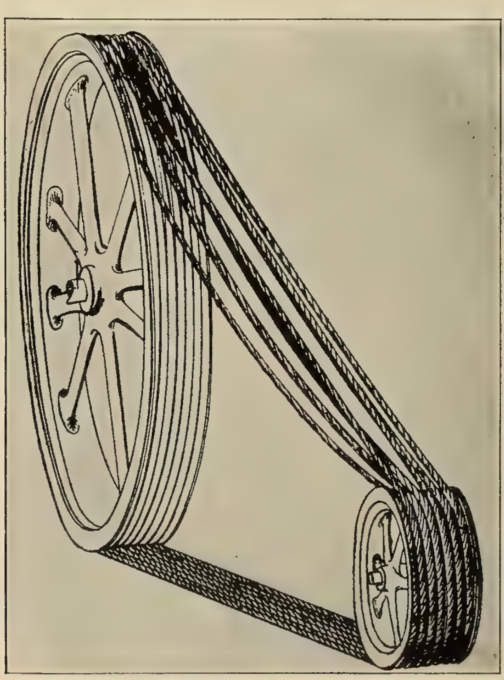


FIG. 2. SINGLE-ROPE BELTS.

According to the Swiss or English systems, if the power to be transmitted is too great for a single rope of practicable size, then two or more ropes are employed, running in grooved wheels side by side. According to the American system, as above outlined, under the same conditions, instead of two ropes, a single rope is carried two or more times around both driver and driven pulleys, and finally by means of a third wheel (Fig. 3) it is conducted from the last groove back to the first groove, and the ends joined to constitute an endless rope for the entire system.

By mounting the third, transfer, wheel upon a movable carriage, and hanging a weight to this, it becomes also a tension device, capable of taking up the slack, equalising the strain on all parts of the rope, and allowing a perfect compensation for hygrometric or other disturbances which affect the length of the rope. The Ameri-

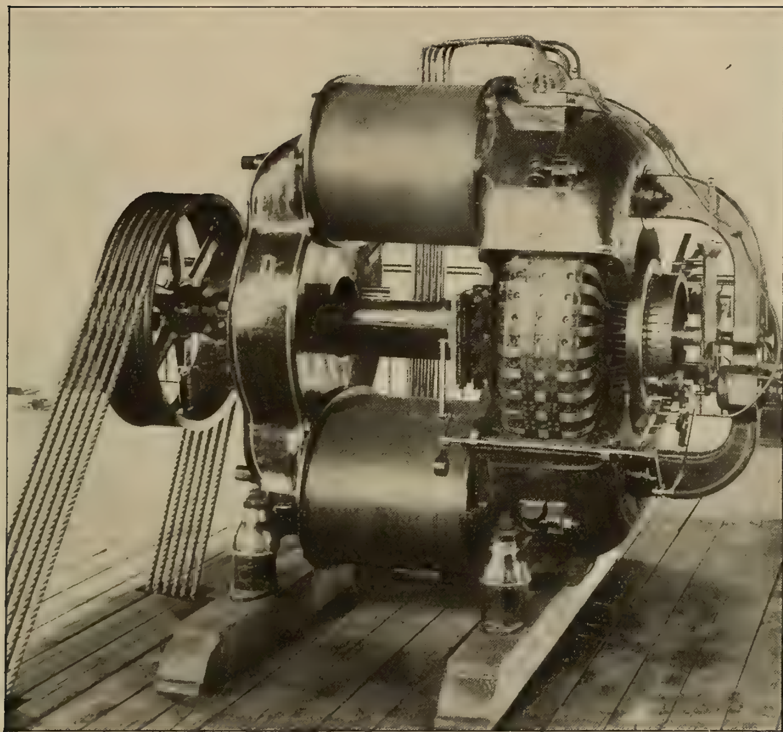


FIG. 4. A ROPE-DRIVEN DYNAMO.

can transmission permits the shafts to be vertical as to each other, or at any intermediate angle to the horizon, and be equally effective because the actual pressure or fractional contact with the wheels is under the control of the tension weight, and thereby any detrimental effect of gravity may be neutralised.

There is also the further advantage that the shafts may be not only independent of each other as to horizon, but also independent of each other as to parallelism, and it is a fact that the rope belt may be caused to operate directly with a departure from parallelism, which would be immediately fatal to a flat belt. By the use of guide pulleys the angular positions of driving and driven shafts may be such as circumstances make desirable, and therefore, in the transmission of power by ropes, the claim is justified that distance and direction are immaterial. These are simple statements of principles involved. In practice, many minor points rise to im-

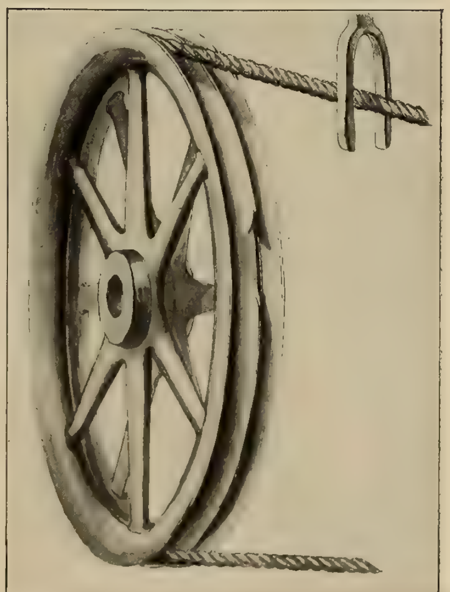


FIG. 5. SHIFTING A ROPE FROM TIGHT TO LOOSE PULLEY.

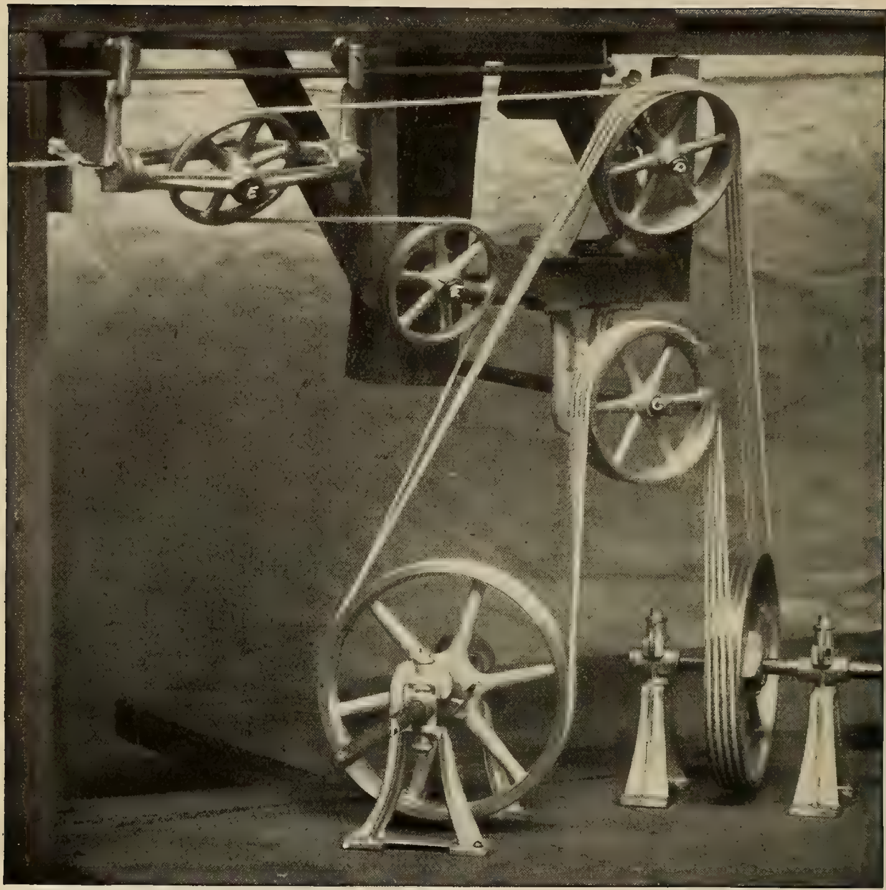


FIG. 6. COUPLING TWO SHAFTS RUNNING IN DIFFERENT DIRECTIONS.

portance, and almost every transmission involves features peculiar to itself.

The equipment of rope transmissions on the American system was commenced in the United States early in the eighties, and operations in that direction have continued to the present time with constantly increasing magnitude of the drives demanded, so that this mode of transmission, after its period of disfavour, doubt and suspicion, has now attained a recognised place in engineering practice. The experimental stage has long been passed, and utility and economy have been demonstrated; but like the practice in any other department of mechanics, there are economical limitations, and the proper recognition of these limitations is the test of the intelligence of the engineer. There are probably mechanical conditions which would render a flat belt more economical than a rope transmission, without in any way detracting from the efficiency of the rope in that position.

With these preliminary statements, the working results of rope transmission will be exhibited by reference to some instance of actual practice.

So far as the writer has observed, the wire rope of Hirn has never been other than a single cable, carrying all the required power. In Hirn's own practice the length of the cable was comparatively short, and the whole distance was made out by relays, the first cable propelling a second, and so on. But in the form adapted to cable railway transmission or haulage, cables several miles in length have been and are in common use.

It was natural, therefore, when, exclusively for indoor use, fibrous ropes were substituted for wire ropes, that one rope of competent dimensions should be employed, and it was not a long step to duplicate the rope when the required capacity became too great for a single rope of practical size.

The essence of Hirn's invention has been described as the conversion of power into speed, and the reconversion of speed into power, but this element did not appear in the English practice, which was nothing more than the substitution of one or more ropes for a more expensive flat belt. The essence of Hirn's invention did, however, reappear in the American system, which, for long distances, has always been operated upon the basis of high speed and diminished diameter of rope, experience having demonstrated the most economical speed to be between 5000 and 6000 feet per minute.

Main engine drives on the American system are mostly simple back and forth passages of the rope over driver and driven pulleys, and differing from the English system only in the fact that a single rope with a slack-taking device is employed instead of a multiplicity of ropes depending on their own gravity for the required tension. But for secondary transmissions, especially of considerable length, and out of doors, a multiplicity of ropes would bring its own difficulties, and the number must, therefore, be limited as well as the size. In the main drive the rope speed may or may not reach the economical limit, but in long transmissions, for reasons above stated, the highest practicable speed is a necessity.

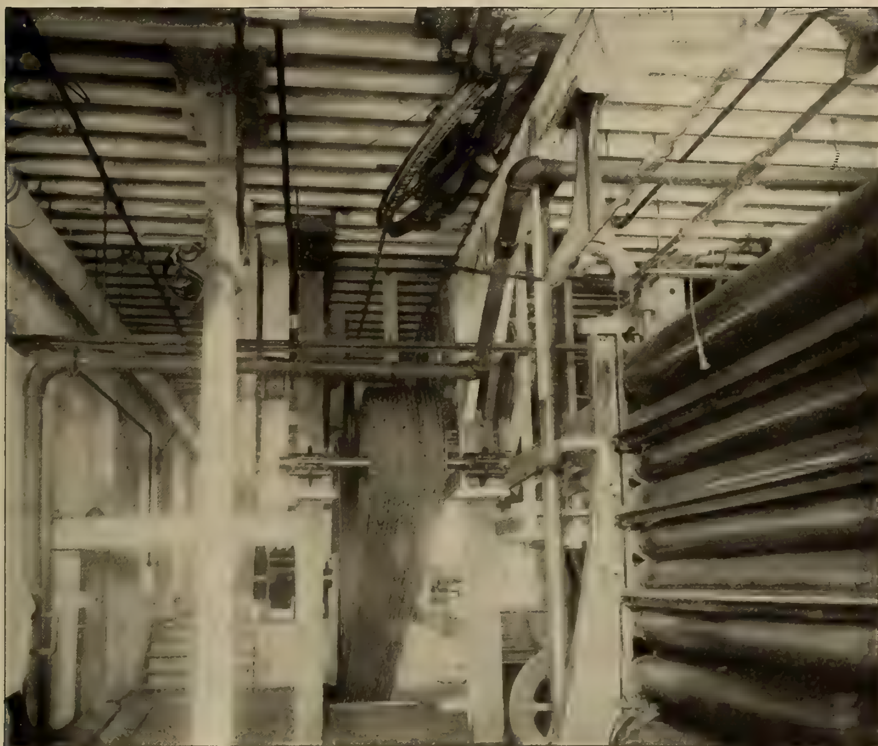


FIG. 7. A ROPE DRIVE IN A PAPER MILL.

In Great Britain hemp ropes have been largely employed. They possess the merit of great flexibility. In the United States manila and cotton have been used, but cotton has not apparently

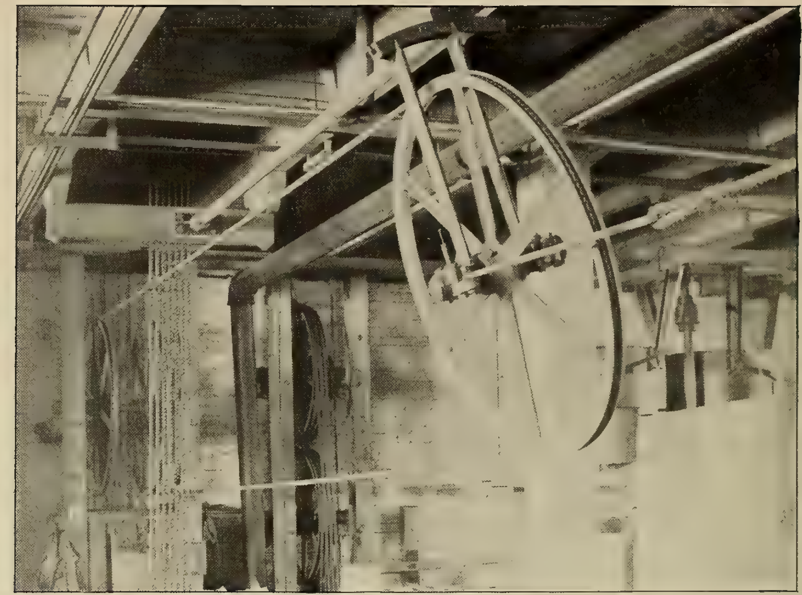


FIG. 8. A VERTICAL DRIVE.

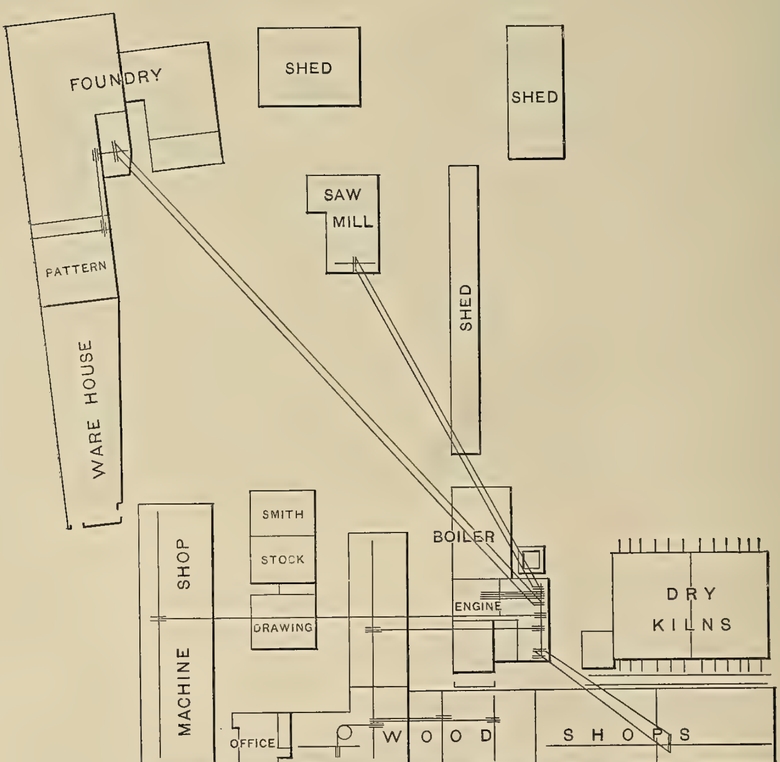


FIG 9. PLAN OF A TYPICAL ROPE-DRIVEN ESTABLISHMENT.

proved so satisfactory as manila for outdoor service. It is more difficult to splice, and stretches enormously. For indoor use these disadvantages are largely counterbalanced by its greater again when it leaves the pulley; hence, for manila ropes the diameter of the pulley ought not to be less than thirty-five or forty diameters of the rope, and sixty diameters are better. A good

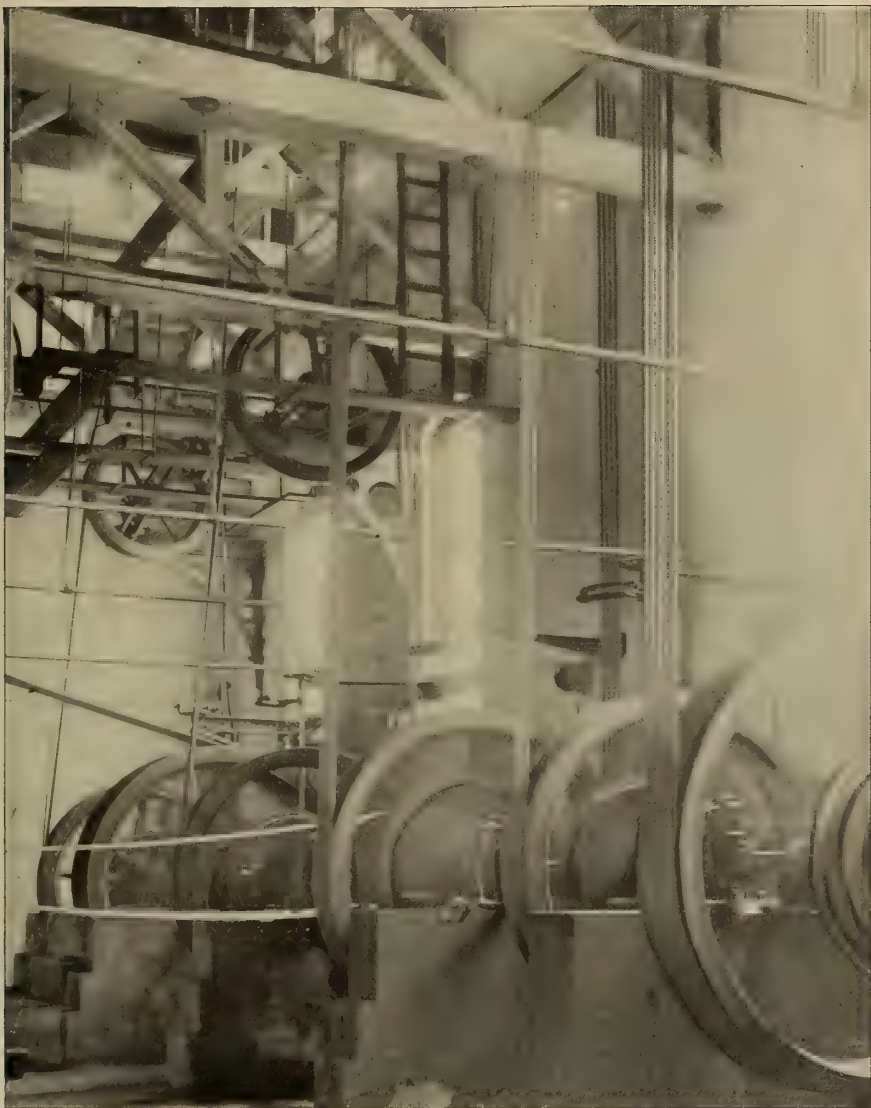


FIG. 10. A TYPICAL AMERICAN ROPE DRIVE.

flexibility and capacity for use with pulleys of smaller diameter. The chief factor in the destruction of the labouring rope is its internal chafe in bending around the pulleys, and in bending rope dressing, faithfully applied, is also of the highest utility in lubricating the rope and preserving it from weathering. It is to be recommended that in designing rope transmissions the bands of the

FIG. 11. ROPES LEADING IN DIFFERENT DIRECTIONS FROM THE JACK SHAFT TOWER.

rope shall all be in the same direction, if possible.

Ropes have been employed to some extent to transmit motion to individual machines, but the conservatism of mechanics as well as the small economic advantage has been an obstacle to their general adoption. The chief difficulty suggested has been in the shift from the tight to the loose pulley, but that has been overcome very neatly by making the tight pulley with a flange on one side only, and providing the adjoining flange of the loose pulley with a gap at one point (Fig. 5). By pressing the rope sidewise it will pass through this gap at its next passage, and ride upon the other pulley until retransferred again in the same way.

An illustration of the use of rope

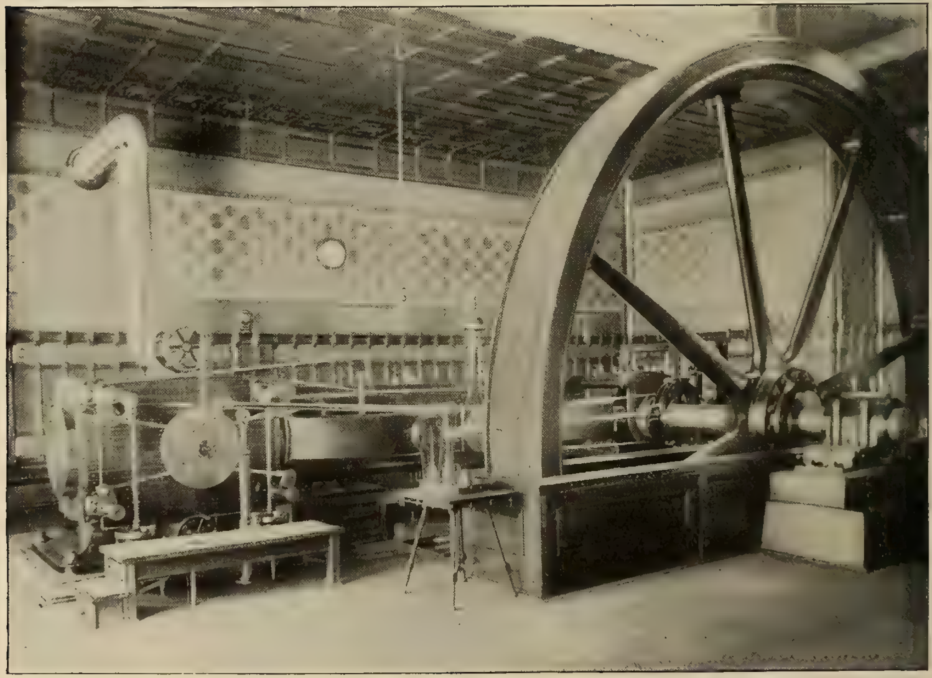


FIG. 12. THE ENGINE ROOM.

transmission for driving individual machines is shown in Fig. 4, where it is employed to drive a dynamo. This is one of twelve in the light and power house of the West Park Commission at Chicago, and it will be conceded that no use of rope could be more delicate as to steadiness and efficiency. This entire plant is driven by two 650 H. P. rope transmissions.

A curious illustration of the flexibility of a rope drive is shown in Fig. 6, in which two shafts on the same level, but running in different directions, are coupled. It will be understood that the coupling would have been the same if the shafts had been on different levels.

Fig. 7 shows a drive in a paper mill. It exhibits conspicuously the inclined transfer wheel, which in this case is also mounted on a traveling carriage, to which the tension weight is attached. Fig. 8 shows a vertical floor-to-floor drive with take-up and transfer wheel moving on a horizontal track.

Rope transmissions on the American system are now in successful use in a vast number of places, and range in length from a few feet upward indefinitely to thousands of feet, and in ca-

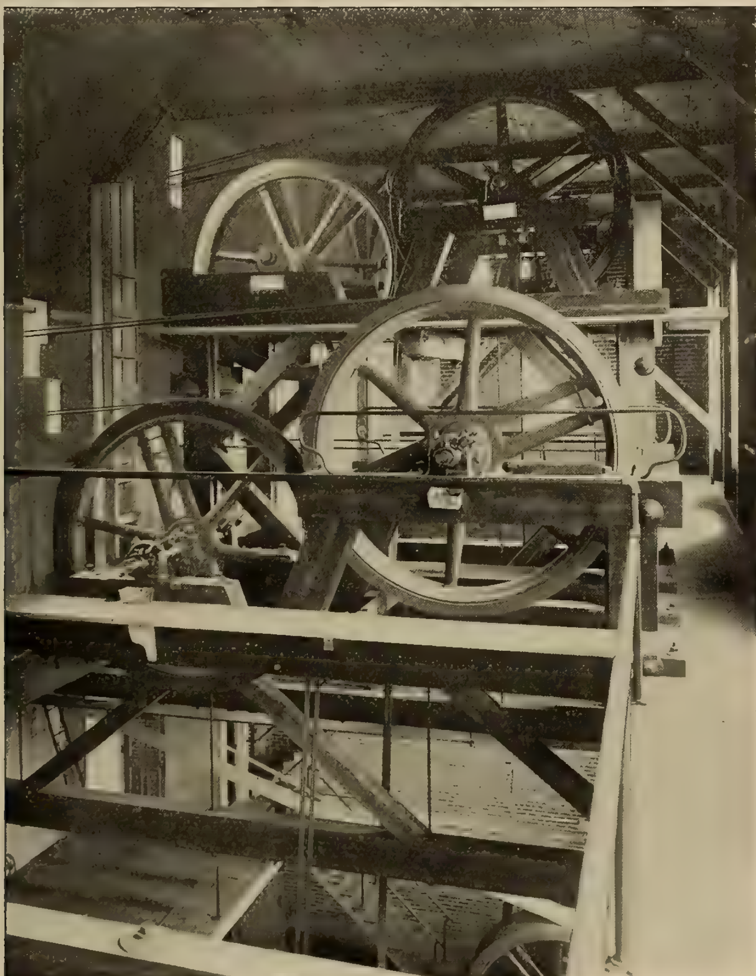


FIG. 13. JACK SHAFT TOWER FOR A ROPE DRIVE.

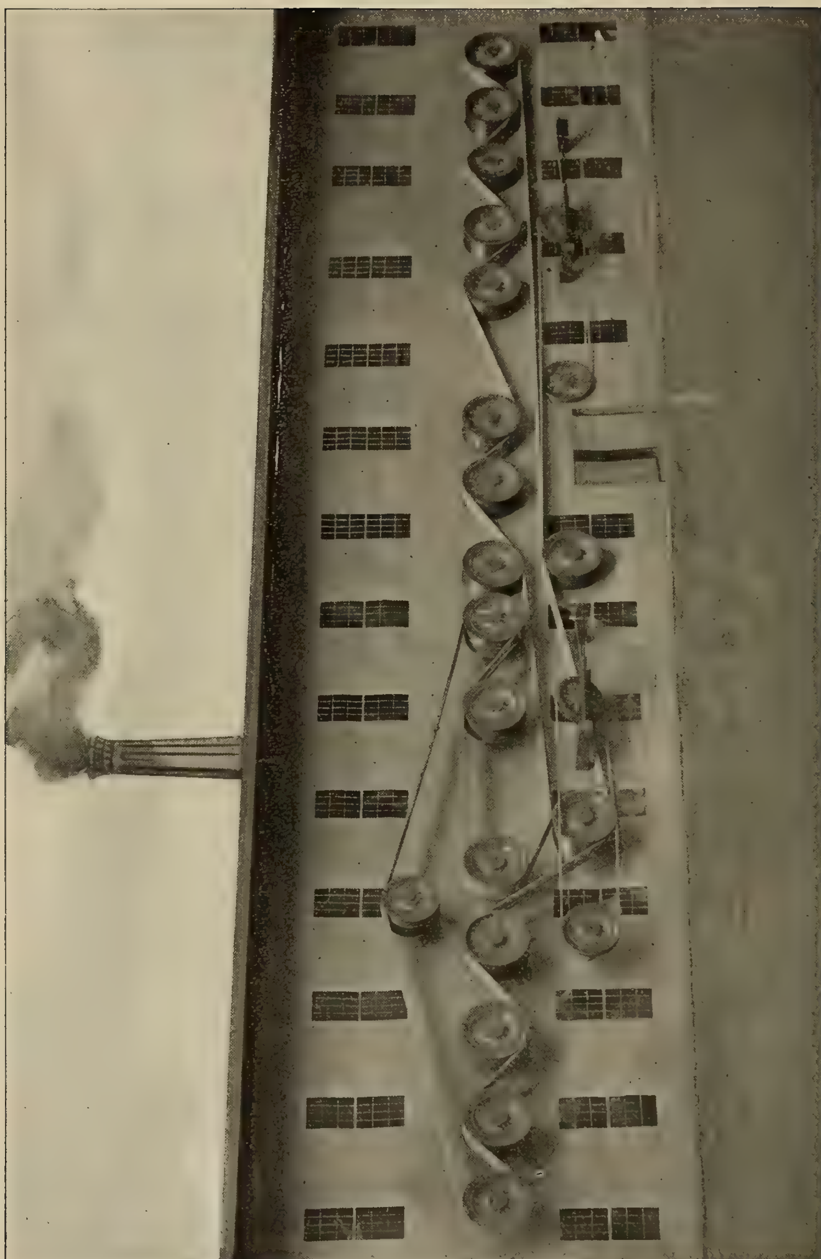


FIG. 14. THE DODGE SYSTEM OF ROPE TRANSMISSION AT THE WORKS OF THE CARTER WHITE LEAD COMPANY, WEST PULLMAN, ILL.

pacity from a fraction of a horse-power upward into thousands of horse-power. One of the big American steel works, the Illinois Steel Company, have in their Joliet plant a rope transmission of 3000 H. P. The Chicago City Railway Company has in one of its stations five rope transmissions of 2000 H. P. each, and in their new West Side power plant, which, when completed, will be the largest electric power plant in the world, they have already installed three rope transmissions of 4000 H. P. each, and three more of equal capacity will be installed in completing the plant.

This last named installation is notable because in adopting rope driving throughout, the engineers were guided by experience gained in the other station where the 2000 H. P. drives had been running several years, and the result of this experience is concisely stated by the officials of the company as follows:—(1) Flexibility of connections between engines and generators; (2) Reduction in weight on bearings from 2 to 4 per cent.; (3) No necessity of disconnecting generators, to repair engines; thus free access to all apparatus for cleaning and repairing; (4) Thorough insulation of generators, thereby lessening accidents; (5) Increase of life in apparatus from 25 to 50 per cent.

It is not questioned that a concentration of the power at one point in the plant is in the direction of economy, but the difficulties attending the distribution to distant points were almost inseparable prior to the advent of the American system of power transmission by ropes. It is true, power has been transmitted to considerable distances by means of shafting, but the friction loss soon imposes a limit.

The American system not only removes all obstacles, but so far eliminates distance and direction as to make at least a formidable rival to electrical distribution. It has been estimated that 3½ per cent. will cover all losses from intermediate resistances on transmissions up to, say, 1000 feet, which will probably far exceed average distances.

The best example known to the writer of what may be done in the way of convenient distribution of power by ropes from a central station is to be found in the establishment of Dodge Manufacturing Company, at Mishawaka, Ind. Fig. 10 shows a part of this distribution. Fig. 9 is a plan of the works.

Motion from the engine is transmitted through a 22-foot main wheel, making 80 revolutions per minute, to a jack shaft by a rope-drive consisting of 13 wraps of 1¼-inch rope. The take-up carriage is overhead, and the tension weight hangs against the wall in the distance.

Upon the jack shaft there are six secondary rope wheels, each provided with a friction clutch coupling, so that it may be cut out without disturbing the action of the others. Thus power from the jack shaft is independently sent to six different points about the works.

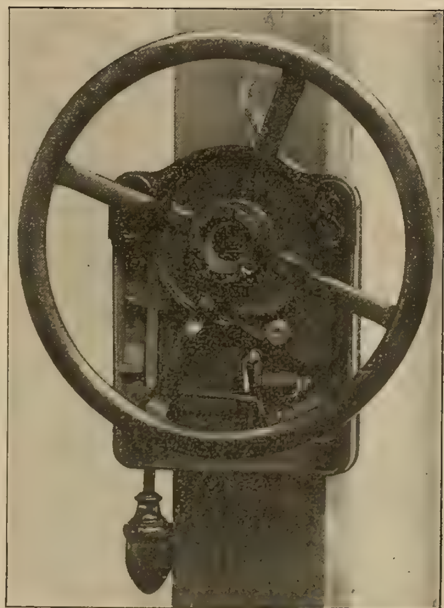


FIG. 15. THE ELECTRIC "LET-OFF."

It will be observed that from the distribution wheels the ropes all pass upward into the jack shaft tower (Fig. 13) forty-five feet above the floor, an elevation sufficient to enable the outgoing ropes to clear the roofs of intervening buildings. The elevation may be more

or less as required, and could be 100 feet as well as 45. In the top of the jack shaft tower they pass over leading wheels, set in the direction required, and the diversity of direction in this case is well shown in Fig. 11, which represents the outside of one side of the jack shaft tower.

To eliminate loss by slip, the transmission ropes pass around idle or winder pulleys and return again to the driving pulley, and in that way increase the surface and arc of contact with the driving pulley to any desired extent. These winder pulleys are shown in Figs. 10 and 13.

A very excellent and useful adjunct to this mode of distributing power is the electrical "let-off' and the "tell-tale". Each clutch is provided with a weight attachment, sufficient, when liberated, to unset the clutch and cut out its wheel, and this weight is sustained by a latch which may be tripped by an electro-magnet (Fig. 15) in an electric circuit, which extends to the most distant parts of the plant. Circuit closers are located at convenient points about the works, and in case of accident, or if for any reason it is desired to shut down a division of the works, it is not necessary to signal the engineer, but simply to close the circuit on the let-off latch, as a result of which the clutch will be immediately thrown out of gear. An annunciator in the engine room at the same time informs the engineer, and a repetition of the annunciator signal directs him to reset that clutch, which it is possible for him to do without affecting the running of the engine or the other drives.

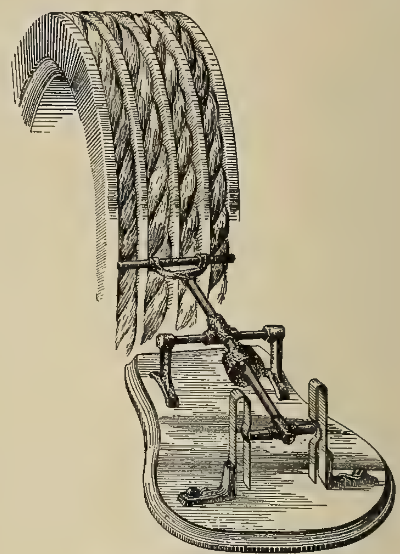


FIG. 16. THE TELL-TALE.

The weak place in any power transmitting rope is in the splice, and to guard against possible disaster consequent upon a broken rope or pulled-out splice, the "tell-tale" (Fig. 16) is placed in the before-mentioned electric circuit, opposite some wheel in the trans-

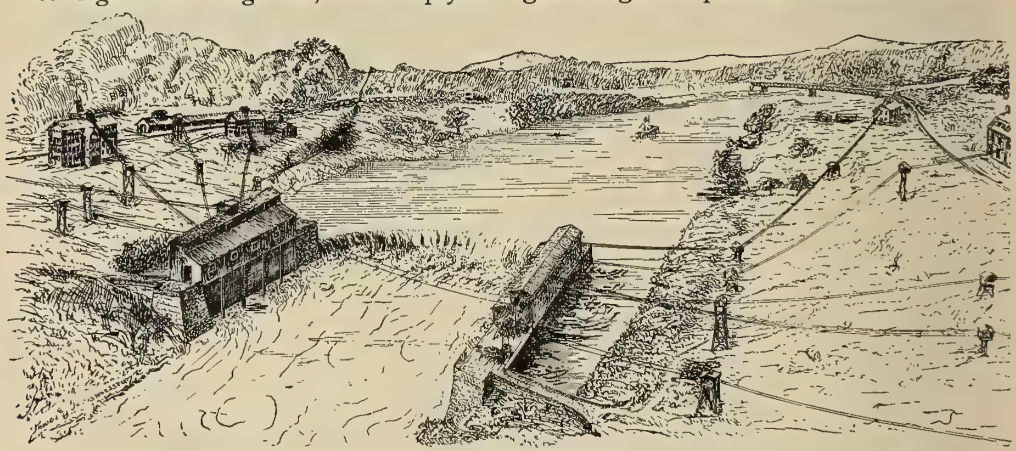


FIG. 17. UTILISING WATER POWER BY ROPE TRANSMISSION.

mission, at a point where centrifugal force will cause the end of a loose strand to stand out from the rope. Contact of such loose end with the cross bar of the tell-tale will cause it to close the circuit, unset the clutch, and ring a signal bell in the engine room, and thus give timely warning of trouble with the rope.

Another scheme of power distribution by means of ropes on the American system is illustrated in Fig. 17, showing the utilisation of water power without the necessity for long hydraulic races, or the location of factory buildings in inconvenient and objectionable places. The flexibility of a rope transmission is well shown in Fig. 14, which, while a picture of a model, truthfully represents the rope drives on the inside of the plant of the Carter White Lead Company, at West Pullman, Illinois.

Judged by the experience of the past, there is no doubt as to the mission of the American system of power transmission by fibrous ropes. Its capacity covers every range of distance, power and position. It may be of interest, in conclusion, to say that experience has not yet shown the working life of a rope, fairly treated, to be less than that of a belt. After seven years' constant labour, the main transmission rope in the Dodge Manufacturing Company's plant was replaced with a new rope on the general suspicion that it might be already weak, but examination showed soundness inside and a probable ability to do service for many years more. Its first cost was probably about one-tenth the cost of an equivalent leather belt, and therefore the interest on the cost of an equivalent belt would replace the rope every year and leave money to spare.

THE PROPER CONSTRUCTION AND USES OF ECONOMISERS.

By Henry G. Brinckerhoff.

A Partial Reprint of a Paper read before the New England Cotton Manufacturers' Association.

THE principle of heating the feed water in a separate vessel, quite apart from the boiler, and thereby utilising the heat in the waste gases, is the function of flue heaters, more commonly called "economisers", leaving the boiler to supply chiefly the heat units necessary for the latent heat of steam. Taking the important steamusers throughout the world, this is a recognised and universally adopted practice. Economisers are not only considered a necessary part of the equipment of every steam plant in Great Britain, but are in operation all over the Continent and as well known in the spinning mills of Russia and India; equally noted among the gold mines of South Africa and the textile factories of China and Japan; while throughout the large manufacturing districts of the United States they are already extensively adopted.

The great loss of fuel as noted between the heat value of coal and the heat taken by the water, has been observed for many years, and numerous have been the appliances to recover it, the simplest and best method appearing to be to pass the waste gases, on their passage to the chimney, around pipes containing water, and thousands of such pipe heaters have been con-

structed by nearly as many makers, yet with an exception of one or two, they have all failed. Disappointment has attended the result of so many economisers or flue heaters, that we find some people to have become skeptical, condemning them all, and stating it to be impossible to build one which will last and give satisfactory results.

The failure of so many flue heaters is attributed to three causes:—

First. Not being made of cast iron, the only practical metal to withstand the corrosive action of sulphurous gases.

Second. Lack of capacity. It takes time to absorb enough heat to make them of practical value; hence the water should be from thirty to fifty minutes surrounded by waste heat.

Third. Lack of automatic cleaning of pipes. Soot being a non-conductor of heat, a slight coating on a limited-capacity economiser would end its usefulness in a few hours after it had been thoroughly cleaned.

The late Mr. Edward Green was the first to develop a flue heater embodying these essential features.

Before he began to devote his whole time and energy to the apparatus that bears his name, he was engaged in general mechanical work and in the construction of large pumping engines for the deep coal mines of Yorkshire, as well as others for draining the fens in Lincolnshire and Norfolk.

Though the patent for his fuel economiser was taken out in 1845, it was not until after the great exhibition of 1851, that steam users seriously recognised the great opportunity for saving that was, by its means, placed within their reach. From that date, however, its success was assured, and the large amounts of coal economised by those steam users who gave it a trial, forced it upon the attention of the remainder of the manufacturing community, with the result that the advantages of the economiser became more and more widely known, and at length almost universally recognised, so that at the present day the invention is used by boiler owners all over the globe.

Briefly stated, the most important details for a well-designed economiser should be an absence of all "made" or packed joints inside of the brick work, and every square inch of internal surface should be easily accessible.

The vertical pipes should be forced into the top and bottom headers by powerful hydraulic pressure, making the joints metal to metal, which is a far superior piece of workmanship than fitting the pipes loosely into the boxes or headers and then rusting in by the use of iron filings and sal-ammoniac. Finally, a rigid test of 350 pounds to the square inch should be applied to each section.

A well constructed economiser, built under the specifications described, should last twenty years with ordinary care and attention. After it has reached that age it can be easily repaired and parts renewed so as to last indefinitely, as an umbrella retains its original individuality after having been fitted with new stick and spokes and after recovering.

The care required consists in blowing off daily at the same time as the boilers. Every three months the soot should be cleaned out of the chamber below, which, at such an interval, is about an hour's job. Once a year, at least, the caps should be taken off and the interior of the pipes inspected. If the water is bad this should be done oftener. There is no reason why the scraper mechanism should not run smoothly for years. This used to be a troublesome point with some of the early makes of economisers.

The general use of compound condensing engines in modern steam plants has enlarged the field and extended the use of economisers, as the exhaust steam is not available for heating feed water except to a limited degree.

A common practice some years ago, was to take a portion of the exhaust steam for heating feed water, obtaining thereby a temperature of about 210 degrees, while with the compound condensing engines it is not generally feasible to get much over 130 degrees, thus making a direct loss in economy for the compound plant as compared with the older ones, to the extent of 7

to 10 per cent. of all the coal consumed, offsetting to that amount the gain obtained by compounding, whereas the higher temperature of the steam demands a higher temperature of feed water, instead of lower, for the proper efficiency and durability of the boiler.

The advantages of the economiser may be summarised as follows:—

First. It is a bona fide saving of an actual waste.

Second. It increases the capacity of the boiler plant.

Third. It saves repairs to the boilers by relieving them of much of the strain of expansion and contraction caused by colder water entering the boilers and mingling with the hotter contents.

Fourth. It prolongs the life of the boilers for the same reason.

Fifth. Saves much cleaning of the boilers, thereby increasing their efficiency because of the precipitation of feed water impurities in the economiser, many impurities not being freed from the water until a high temperature is reached. This fact, and the slow movement of water in the economiser, is the reason that this apparatus removes so much more foreign matter from the feed than the other types of heaters.

Sixth. The economiser is especially desirable where the work fluctuates. A large amount of power suddenly withdrawn drops the boiler pressure, while fresh coal in the furnace and cold feed water entering the boilers make matters worse, a condition frequently observed in bleacheries and electric plants. Gauge pressure is seldom observed to drop when an unusually large amount of feed water is being forced into the boiler, where it has been previously heated in an economiser.

Seventh. Where hot water can be put to any use in processes of manufacture, it can be obtained free of cost by drawing it from the economiser; bleachers and dyers, particularly, take advantage of this opportunity for their kiers and dye tubs. Where mills are heated during the winter by hot water, a part of the economiser can be included in the circulating system, supplying the heat necessary entirely by the waste gases. This has been done by some large mills.

In conclusion I may say, it is the general opinion of those owning economisers, and others having them in their charge, that it makes easy working conditions in the boiler room.

MODERN REFRIGERATING METHODS.

By E. H. G. Brewster.

AN ICE FACTORY, EQUIPPED BY THE PULSOMETER ENGINEERING CO., LTD., LONDON.

THE most ancient method of making ice is practised in India. Holes are made in the ground, dry straw is put at the bottom of these, and on it, at the close of the day, are placed pans of water which are left until the next morning, when the ice that is found within the pans is collected. This industry is carried on only in districts where the ground is dry and will readily absorb the vapour given off from the water in the pans. The freezing, of course, is due to the great amount of heat absorbed by the vapour in passing from its liquid to its gaseous form.

Another process was practised in the days of ancient Rome when the wealthy are said to have had their wines cooled by having the bottles placed in water into which saltpetre was thrown, the bottles being the while rotated.

Dr. Cullen, in 1755, discovered that the evaporation of water could be facilitated by the removal of the pressure of the atmosphere, and that by doing this water could be frozen. Nairn, in 1777, discovered that sulphuric acid would absorb the vapour of water if placed in a second vessel separate from that containing the water, but connected with it. This discovery he put to use in 1810 by constructing an apparatus for absorbing the vapour of the water that it was de-

sired to cool or freeze. This apparatus greatly facilitated the freezing operations of a vacuum freezing machine.

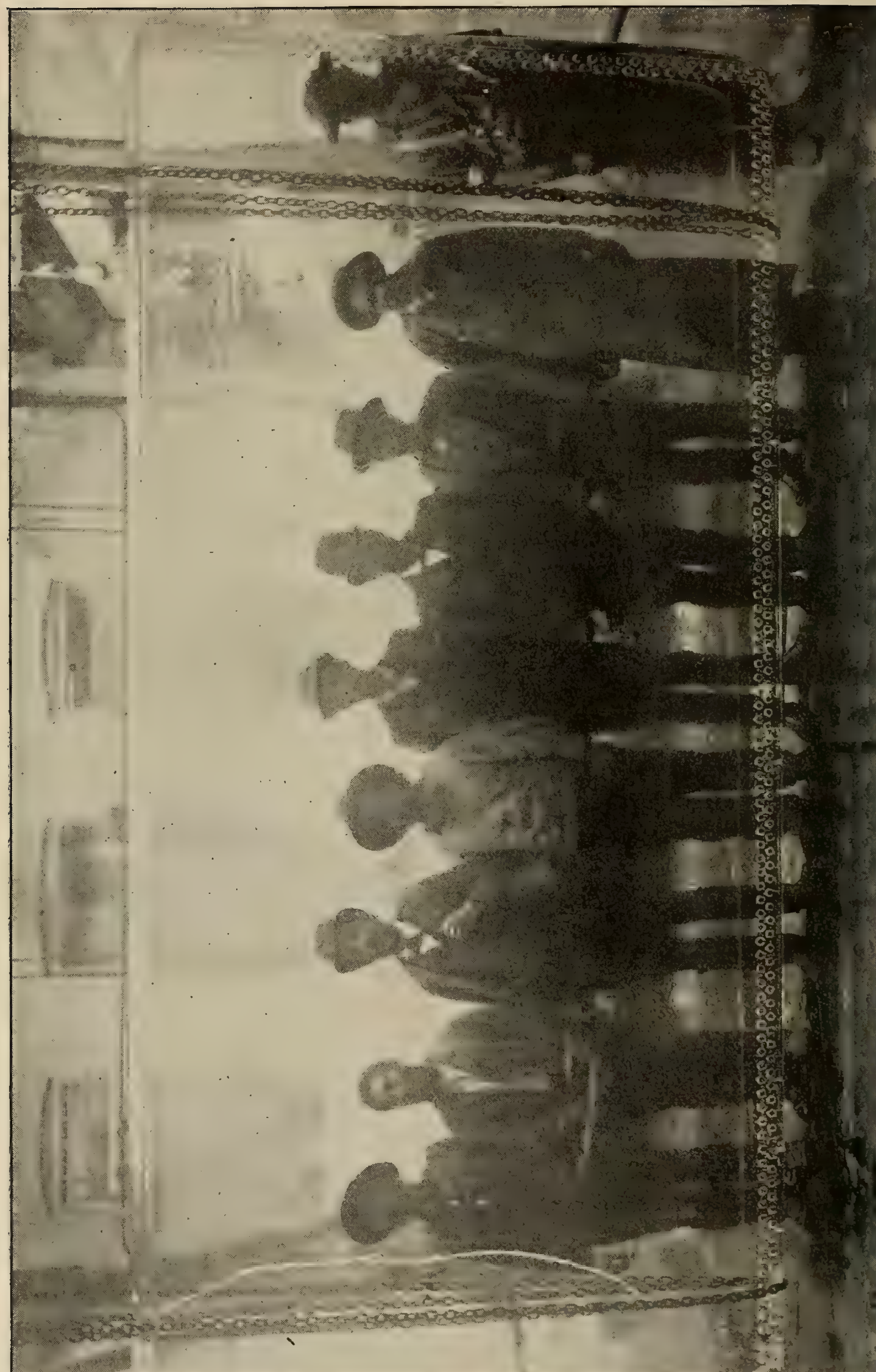
Jacob Perkins was the father of what is now known as the compression system, having invented the first machine of the kind in 1834, and, as these machines, improved, are at the present day more in use than any other, a description of Perkins's patent may be of interest. His apparatus consisted of an insulated vessel, in which was enclosed a second vessel containing ether; a vapour pump; a worm and worm-tub; a tube between the second vessel and the pump; another between the pump and the worm; a third between the worm and the bottom of the ether vessel; and the necessary valves.

As afterwards constructed, the apparatus was made up of a jacketed pan within which was the water to be cooled; an insulated box, in which was placed the pan; a pump to extract the vapour from the jacket; a worm in which the vapour was condensed after it left the pump; a worm tub containing cold water to cool the worm, and by means of the latter the vapour within it; and pipes connecting the top of the pan jacket to the pump, the pump with the upper end of the worm, and the lower end of the worm with the under side of the pan jacket. The refrigerating agent used with this apparatus was one derived from the destructive distillation of caoutchouc. James Harrison improved upon Jacob Perkins's apparatus in 1856, and it has been further improved by many others since.

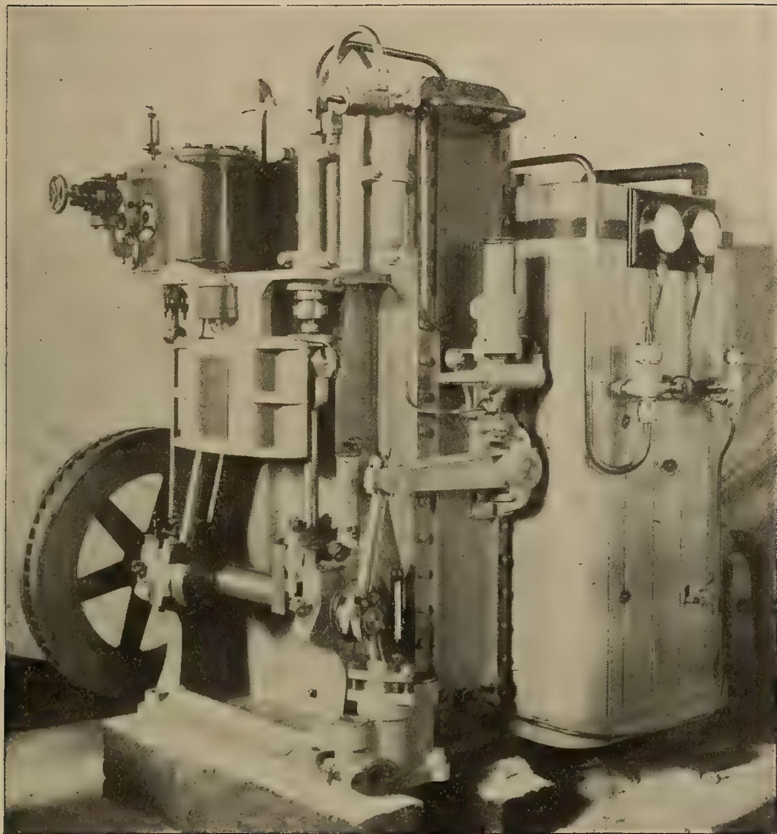
The first absorption apparatus for the reduction of temperature was invented by Ferdinand Carrè, about 1850. The employment of air as a refrigerating medium was commenced by Professor Piazzi Smyth, in England, and Dr. Gorrie, in America, the former making experiments in connection with the matter in 1839; but it was not until after the famous experiments of Dr. Joule in 1845 that any great advance was made in the use of air for the purposes of refrigeration.

The results of Dr. Joule's experiments were described in a paper published in the *Philosophical Magazine* of 1845, and

STORAGE ROOM OF AN ICE-MAKING PLANT EQUIPPED BY THE DE LA VERGNE REFRIGERATING MACHINE CO., NEW YORK.



A CAKE OF ICE MADE BY THE FRICK COMPANY'S PLATE ICE PROCESS.



MARINE TYPE OF CARBONIC ACID REFRIGERATING MACHINE MADE BY MESSRS. J. & E. HALL, LTD., LONDON.

by them he showed that the mere expansion of air, without its doing some work, would not decrease the temperature of the air. His own words are:—"No change of temperature occurs when air is allowed to expand in such a manner as not to develop mechanical power." And he further says:—"No cold was produced, because the momentum of these particles was not permanently converted into mechanical power; but had the motion of the air from one vessel to the other been opposed in such a manner as to develop power at the outside of the jar, which might have been accomplished by means of a cylinder and piston, then loss of heat would have occurred." Refrigeration or reduction of temperature may be brought about in various ways.

1. By the evaporation of liquids having low boiling points.

2. By the melting or dissolving of solid bodies in water, *e.g.*, ice in water.

3. By transferring the heat of one body to another; which can be done only when one is of a higher temperature than the other.

4. By the consumption of heat by causing work to be done by the substance used as the cooling agent.

Cooling by the evaporation of a liquid is brought about by the absorption of heat that takes place when a substance passes from the liquid to the gaseous condition. This operation, in order to be of use commercially, must take up a very appreciable amount of heat and the fluid must have a low boiling point. The amount of heat taken up in the change

of form just mentioned is known as the latent heat of the substance. All liquids do not have similar boiling points and latent heats; in fact, no two are alike. The following list of a few substances, with their boiling points at atmospheric pressure, and their latent heats, will show this:—

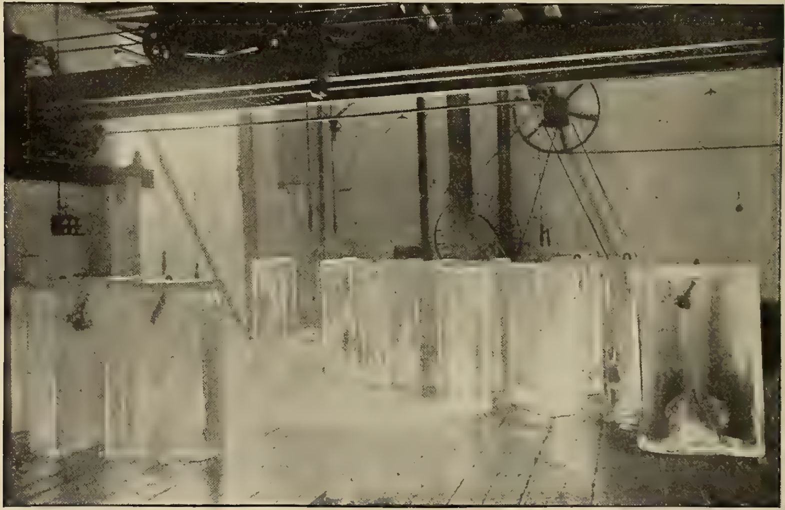
	Boiling points.		Latent heat. B. T. U.
Water	+212.°o	Fahr.	965.7
Anhydrous Ammonia	−37.3°	"	895.0
Alcohol	+173.°o	"	457.0
Carbonic Acid	−125.°o	"	298.0
Carbon bisulphide	+115.°o	"	156.0
Naphtha	+320.°o	"	
Ether Sulphuric	+ 96.°o	"	174 0
Ether Methylic	− 10.°5	"	473 0
Linseed Oil	+600.°o	"	
Mercury	+662.°o	"	5.0

In cooling processes in which a solid is used for the purpose, the plus quantity of heat in the substance to be cooled passes into the cooling substance, but the total heat of the cooled and cooling substances, after the operation, will be found not to accord with what might have been expected if one were to rely on the temperatures registered by the thermometers. This is due to the fact that heat is absorbed in the transformation of the solid into a liquid. Ice, for instance, at 32° F., in passing into the liquid state, absorbs 142.5 heat units, and the resulting liquid, water, will be found not to register a higher temperature than 32° F., but the air or other substance that surrounded the ice will have lost 142 units of heat, notwithstanding this. Below are given the latent heats of liquefaction, or fusion, of some solids:—

	B. T. U.
Ice	142.4
Nitrate of Sodium	113.2
Zinc	50.6
Platinum	48.8
Silver	37.8
Tin	25.5
Lead	9.5
Mercury	5.1

The method of cooling one body by another of lower temperature, through the transmission of heat by conduction, is exemplified by those processes in which are employed a solution of chilled brine which is circulated in pipes within refrigerating chambers.

It is impossible here to enter into the theory of each class of apparatus, and the writer confines himself simply to a general description of some of the machines in current use, selecting first what is known as the absorption machine. One form of this consists of six cylindrical vessels, some piping, and a small pump. The first vessel, a horizontal one, is called the "generator," and into it is placed a charge of ammoniacal liquor, which is heated, preferably by means of steam passing through a coil of pipes



READY FOR THE MARKET.

A COLD STORAGE ROOM FITTED UP BY THE PENNSYLVANIA IRON WORKS CO., PHILADELPHIA.

inside the generator. The heat causes the ammonia to be evaporated from the liquor, and, on rising, to pass through the second vessel, a vertical one (as are the other four), which is known as the separator, but in American practice it is called the analyser, and is situated on the top of the generator. Its duty is to separate from the ammonia any water vapour that may have been carried away with it. It is similar in character to some of the upper parts of a good rectifying still, and acts in a similar manner.

The ammonia vapour is then led to a coil of pipe in the third vessel, which is called the condenser. This is filled with cold water, which is constantly replenished. The ammonia is converted into its liquid state by means of the tension of its own vapour and the cold bath that it has received. From the condenser the ammonia passes into a second series of coiled piping in the fourth vessel,—the cooler,—in which it is allowed to expand, and in doing so takes up a large amount of heat from the brine with which the cooler is filled and which surrounds the coils of pipe containing the ammonia. The heat taken up is that required for the transformation of the ammonia from a liquid to a gas, and is equal to 895 thermal units per pound. The cooled brine is then used for any purposes that may be desired, such as ice making, the chilling of meat stores, etc., being circulated through pipes around the places or amongst the substances to be cooled.

After having accomplished its work the ammonia gas passes into the fifth vessel, the absorber,—where it meets with the original liquor from which it was first distilled in the generator, and becomes absorbed by it. From the absorber the saturated liquor is pumped through the last of the six vessels, called the economiser,—in America, the exchanger,—where it meets with the liquor from the generator on its way to the absorber, and finally reaches the generator, to again go through the cycle of operations just outlined.

Brine has been mentioned as the agent by means of which heat is abstracted from the substances or chambers to be chilled or cooled. This is a solution in water of chloride of sodium, or chloride of calcium, for either can be used. In the United States chloride of sodium is more frequently used than the other, owing probably to the difference in price, as chloride of calcium has advantages over the former; both are in use in England, but the preference is generally given to brine made with chloride of calcium as the pipes keep cleaner, it causes less wear and tear, and it is a better conductor of heat.

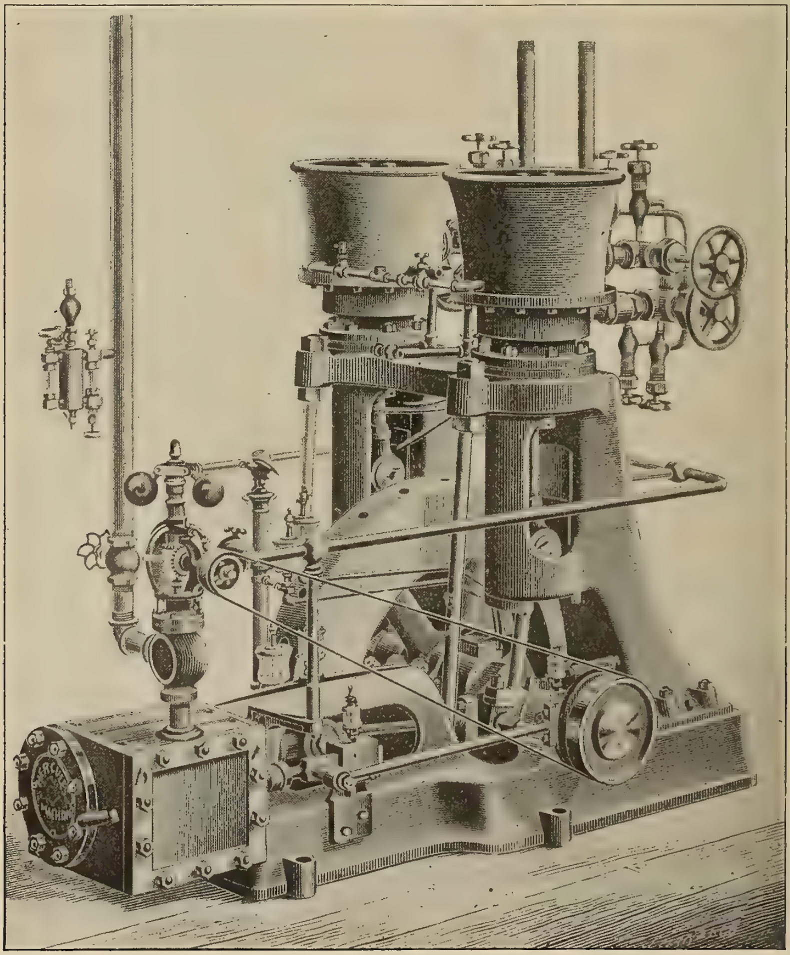
Brine can be raised to a higher temperature without boiling than can water by itself, and its freezing point is considerably lower in temperature than that of water, depending upon the strength of the solution, as shown by the following tables:—

SOLUTION OF CHLORIDE OF SODIUM.

Percentage by weight.	Freezing point.
1	30.5° Fah.
5	25.2 "
10	18 7 "
15	12.2 "
20	6.1 "
25	0.5 "

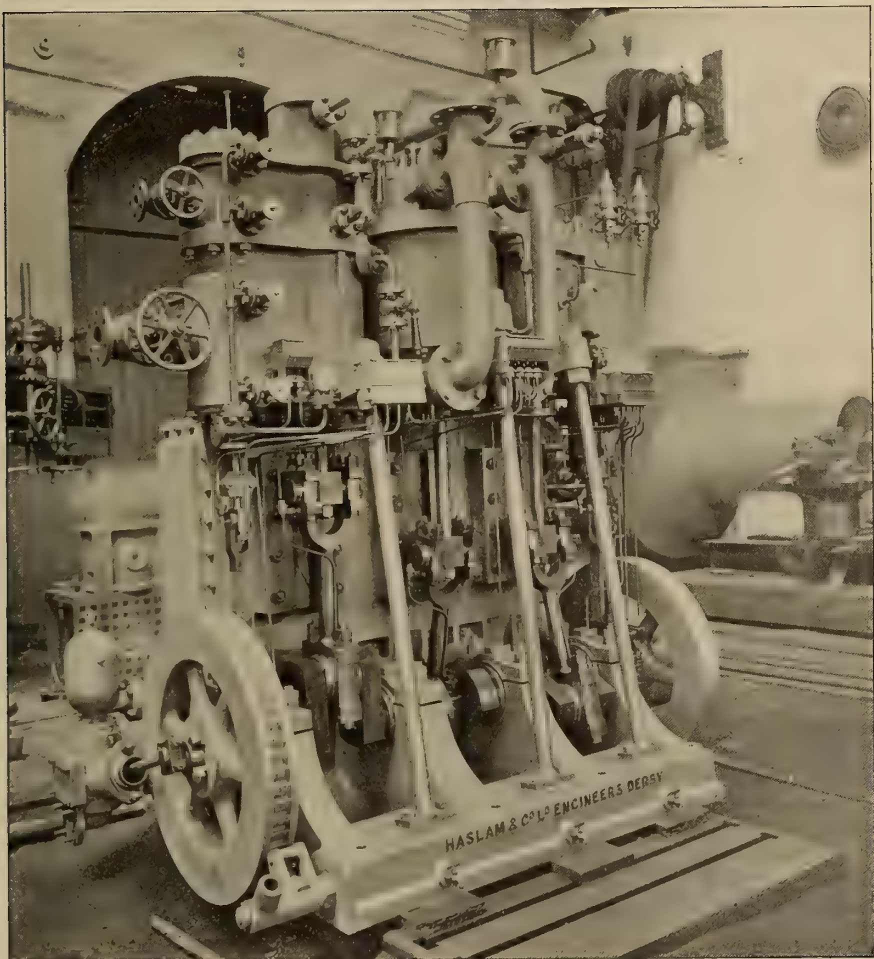
SOLUTION OF CHLORIDE OF CALCIUM.

Percentage by weight.	Freezing point.
1	31.0° Fah.
5	27.5 "
10	22.0 "
15	15.0 "
20	5.0 "



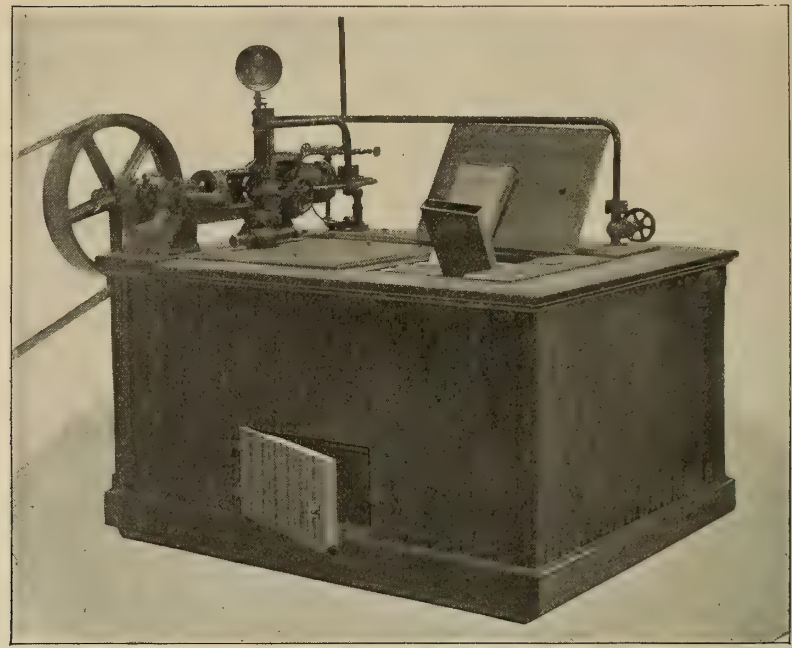
HERCULES ICE MACHINE, STEAMSHIP PATTERN, BUILT BY THE E. P. ALLIS CO., MILWAUKEE, WIS.

In deciding upon the percentage of the salt in the brine, care has to be taken that this is not too great, as the higher it is, the lower will be the specific heat of the solution ; and, further, if the salt is greatly in excess, a danger is run of the pipes becoming choked by salt deposits.

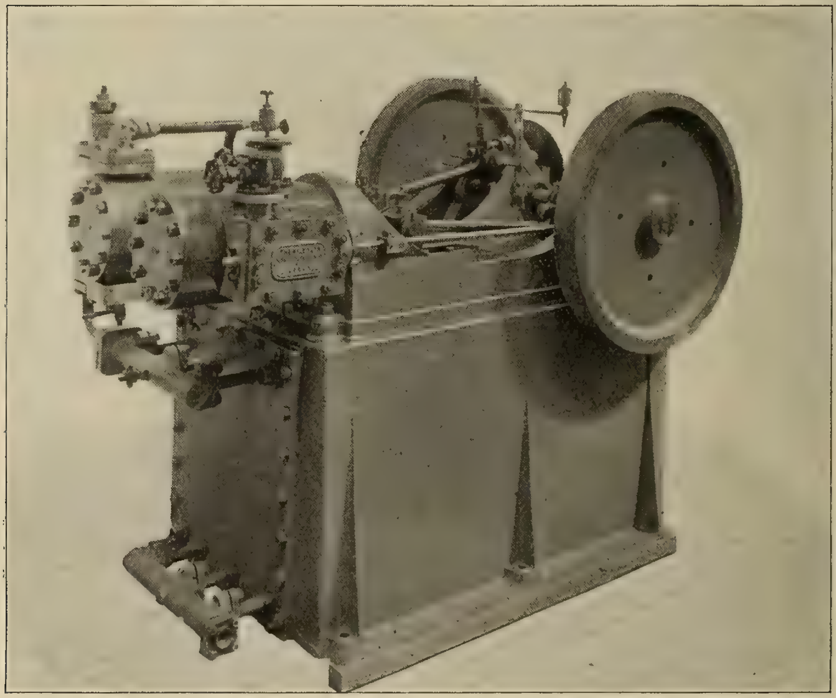


A COMPRESSED AIR REFRIGERATING MACHINE AS USED ON BRITISH BATTLESHIPS. BUILT BY MESSRS. HASLAM & CO., LTD., DERBY, ENGLAND.

Another type of heat-reducing apparatus works without any direct application of heat, and relies for its successful operation upon a vacuum pump and sulphuric acid. When ice is required to be made, or water cooled, the water is placed in a glass vessel which is connected with an air pump and a vessel holding sulphuric acid having usually a specific gravity of 1.846. The abstraction of the air from the vessel holding the water reduces the pressure upon it, and the vapour that arises from the water in consequence of this reduction of pressure is absorbed by the sulphuric acid. The partial evaporation of the water thus brought about causes it to cool, the amount of heat extracted being 966 thermal units per pound of vapour. It will be well, perhaps, not to pass over in entire silence a comparatively insignificant branch of refrigeration,



A PORTABLE REFRIGERATING MACHINE, BUILT BY THE NEWBURGH ICE MACHINE AND ENGINE CO., NEWBURGH, N. Y.



AMMONIA COMPRESSOR AND ENGINE COMBINED, WITH CONDENSER COILS ENCLOSED IN BOX BED. MADE BY THE KILBOURN PATENT REFRIGERATOR CO., LTD., LIVERPOOL.

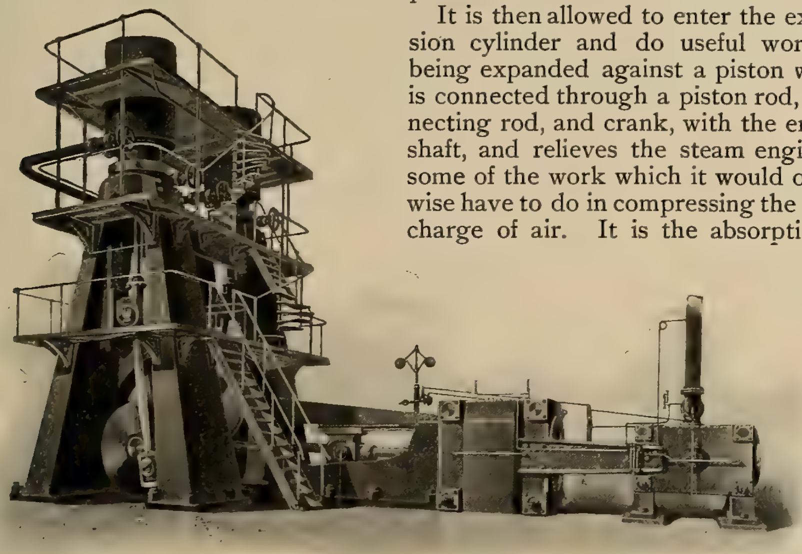
viz., the use of freezing mixtures. Below are given the compositions of a few freezing mixtures and their frigorific capabilities:—

	Fall in Temperature.
Snow, 4; muriate of lime, 5	72°
" 1; chloride of sodium or common salt, 1	32°
Snow, 2; chloride of calcium crystallized, 3	82°
" 3; potassium, 4	83°
Sulphate of sodium, 6; nitrate of ammonia, 5; dilute nitric acid, 4	64°

The next class of heat-reducing apparatus to which attention should be drawn is one that has been of considerable importance in the past, and in the present to some extent, as by its means the enormous strides in the use of heat reducers has been principally brought about. This is the compressed air machine. This type of machine depends for its action upon the well-known fact that mechanical work and heat are interchangeable.

Air compressing machines, generally speaking, consist of a combination of a steam engine, an air compressor, a cooler, and last, but not least, an air expansion cylinder. The air after compression is cooled by means of water. In some machines this is injected into it; in others, the compressed air is driven through pipes surrounded by water, which is circulated around them. This cooling process extracts all the heat that has been imparted to the air during its compression and leaves it at the temperature of the water. The air then passes through a series of pipes around which the cold air from the refrigerating chambers, in the case of a cold meat or other store, is allowed to circulate, by which means the compressed air is still further cooled.

It is then allowed to enter the expansion cylinder and do useful work by being expanded against a piston which is connected through a piston rod, connecting rod, and crank, with the engine shaft, and relieves the steam engine of some of the work which it would otherwise have to do in compressing the fresh charge of air. It is the absorption of the heat by the mechanical work done in the expansion of the air against the piston in the expansion cylinder on which the efficiency of the cold air machine depends. Excellent machines of this class have been built.



AMMONIA COMPRESSION REFRIGERATING MACHINE, BUILT BY THE FRICK COMPANY, WAYNESBORO, PA. ENGINE, 26″ X 50″ X 48″. COMPRESSORS, 27″ X 48″.

Jacob Perkins, in his original compression machine, proposed to use ether as his refrigerative agent; other substances since then have been used, prominent among these being sulphurous acid, carbonic acid, and ammonia. The last-named substance has many advantages over the others; it possesses the property of storing up a considerable quantity of latent heat when vapourised, a quantity second only to that possessed

by water; it has a low boiling point and a high vapour tension; and it is in consequence of these traits in its character that it is being more largely used at the present time as an agent of refrigeration than any other substance. Probably the next substance in favour is carbonic acid, which liquefies at a pressure of 540 pounds, and has a vapour tension of 521.85 pounds at a temperature of 32° F.

The present-day ammonia compression machines may be said to consist of an engine, compressing pump, and condenser or cooler, and they are somewhat similar in construction, generally speaking, to a compressed air cooling machine with the air expansion cylinder left out, but modified to suit the conditions met with in dealing with the various refrigerating agents used. The ammonia compression machines and carbonic acid compression machines are much more economical in their working than cold air machines, and, further, do not occupy so great an area. The drawbacks to them are the refrigerating agents used, as both are inimical to human beings. But with the good workmanship and care exercised in building these machines, accidents are comparatively rare.

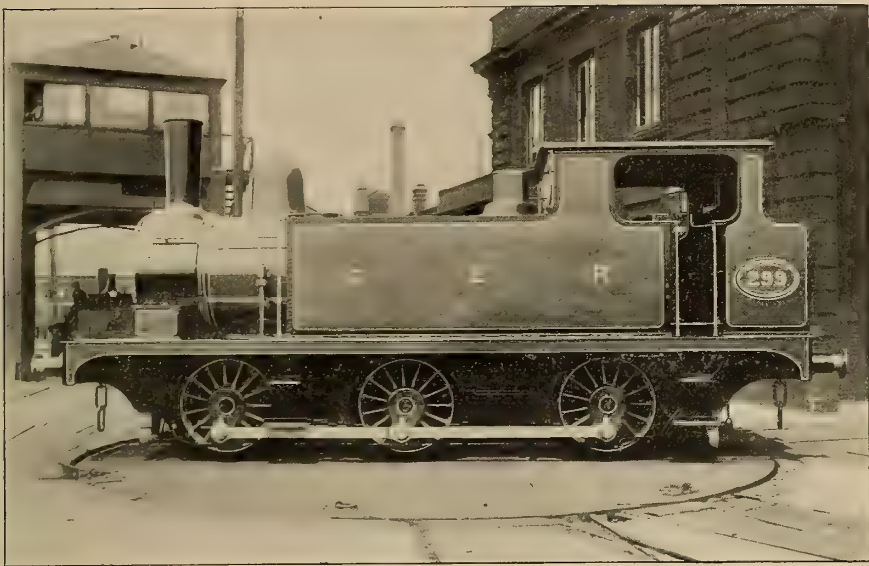
JAMES HOLDEN.

A Biographical Sketch.

AS the locomotive superintendent of the Great Eastern Railway in England, James Holden has become known in the engineering profession on both sides of the Atlantic, principally, perhaps, in connection with his extended and successful experiments with liquid fuel burning on locomotives.

Mr. Holden at the outset of his career, served an apprenticeship in the workshops and drawing office of the North Eastern Railway—then the York, Newcastle and Berwick—at Gateshead, under the late Mr. Edward Fletcher. At the expiration of his articles he remained for some time in the drawing office and was for two years a foreman in the locomotive shops of the company at York, leaving to take the position of manager in a small general engineering shop in Sunderland. About two years afterwards he re-entered the service of the York, Newcastle and Berwick Railway Company as an inspector in the running department, where he remained till August, 1865.

At this time the Great Western Railway Company had decided to spend something like £250,000 on new narrow-gauge rolling stock, and the late Mr. Joseph Armstrong, the locomotive superintendent of that railway, selected Mr. Holden to design, and afterwards inspect the building of, the stock, which was constructed by contracting firms in various parts of the country. Stationed first at London, he was afterwards put in charge of the carriage and wagon shops at Shrewsbury, to which Chester was soon added. In 1873 he was removed to Swindon to take the management of the company's large carriage and wagon works at that station. On the death of Mr. Armstrong and the appointment of Mr. Dean, his principal assistant as his successor, Mr. Holden was appointed principal assistant to Mr. Dean, a post which he held until 1885, —a service of twenty years less seven days. His appointment by the directors



A SHUNTING TANK ENGINE ON THE GREAT EASTERN RAILWAY, ENGLAND

of the Great Eastern Railway Company to take charge of their locomotive, carriage and wagon department dates from August, 1885.

The Great Eastern train mileage for the preceding twelve months amounted to 14,649,345, and the rolling stock consisted of 665 engines, 3068 carriages, and 13,928 wagons. At the present time the mileage is at the rate of 20,604,954 per annum and the rolling stock consists of 993 engines, 4420 carriages and 19,660 wagons. The Great Eastern Railway was at one time preeminent for its variety of engine types, many of which were not altogether modern. These had been somewhat reduced in number, but much remained to be done. Mr. Holden adopted the wise policy of breaking them up and replacing them with engines better suited to the requirements of the traffic and with interchangeable details. His single-wheel express, four-wheel coupled express, and four-wheel coupled "mixed traffic" (passenger and goods) engines interchange in most details. Some of these engines are here shown and also the shunting tank engines with which he replaced the old tender and

A SINGLE-DRIVER EXPRESS LOCOMOTIVE, FITTED WITH LIQUID FUEL APPARATUS.

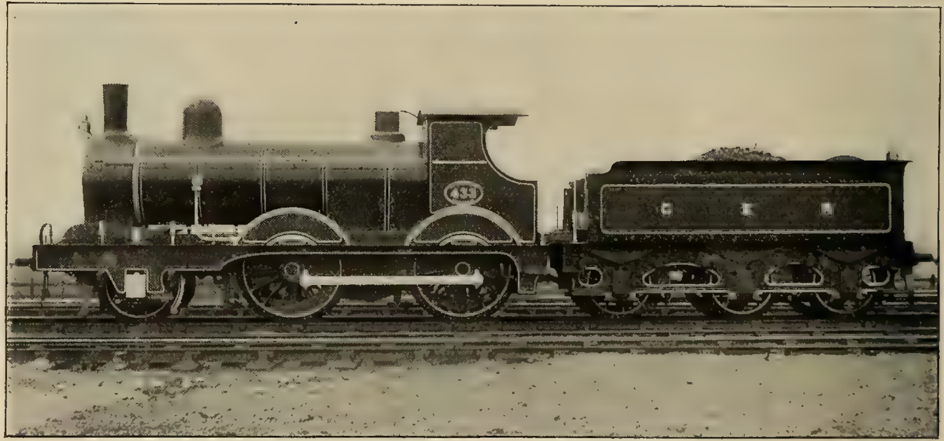
other engines of various descriptions which had been relegated to the marshalling yards when beyond service for train work.

The responsibilities of the locomotive superintendent of a large railway company are considerable. On the Great Eastern Railway the number of hands employed in the locomotive department is about 8000. The expenditure for twelve months is little short of a million sterling, exclusive of large sums spent from time to time on capital account or additional engines and rolling stock, all of which are manufactured at the company's workshops at Stratford, where Mr. Holden has his chief offices.

It is on record that in 1891 an engine was erected at the works from first to last in ten hours and was despatched to Peterboro on the same day with a train of coal empties. After running 36,084 miles it was brought in for inspection and slight repairs, and has not been in the shops since. Contiguous to the running sheds at this station there is an enginemen's dormitory, designed and built by Mr. Holden, his object being to provide comfortable quarters for the large number of enginemen and firemen terminating their duty at the London end, away from their homes. This dormitory is the most complete in the world and is provided with dining and smoking rooms, baths, library, kitchen, etc. It is lighted by electricity, and the beds are each in a separate cubicle. Up to date it has had 100,000 occupants.

A matter, perhaps worthy of special mention, is the introduction on the Great Eastern Railway of the Great Western practice of using steel underframes for wagons in place of timber. Mr. Holden points out that in addition to the immunity from damage during shunting operations, and the vastly longer life of steel, each wagon, so framed, means the use of an additional ton of British-made steel and the decrease of one load of imported timber. As it is estimated that there are about a million and a half railway wagons in Great Britain, the general substitution of steel for timber would have an important bearing on the trade of the country.

But, as previously mentioned, it is by his improvements in liquid fuel burning apparatus that Mr. Holden's name is best known to the public. There had been many previous attempts to utilise crude and refuse mineral oils as fuel, and a locomotive fired with oil had been unsuccessfully experimented with on the London, Brighton and South Coast Railway some years ago. In Russia, where oil is so much cheaper than coal, Mr. Urquhart's well-known system has been at work for years on the Grazi and Tzaritzin Railway, but his ap-



A MIXED TRAFFIC ENGINE ON THE GREAT EASTERN RAILWAY.

paratus, like most others, necessitates a specially constructed furnace in which it is not possible to consume coal. Mr. Holden's aim was to design an apparatus which, without any alteration of existing furnaces, should be perfect as an oil burner and yet permit of coal being used with equal facility when rendered necessary by circumstances.

The apparatus has been so often described that it suffices to say that as the supply of oil, steam, and air can be regulated to a nicety, perfect combustion is ensured, with consequent freedom from smoke. This feature has recently led to its adoption by the Austrian State Railway authorities for the engines,—thirty-seven in all,—working the passenger and goods-train service through the Arlberg tunnel, 6½ miles in length, where it was found that with an easterly wind blowing, no system of ventilation sufficed so long as coal-burning engines were employed.

Current Topics.

One means of obtaining relief from smoke from boiler and other chimneys was, years ago, found in simple forms of apparatus in which the chimney gases were more or less thoroughly washed by sprays of water. These latter were intended to, and in many cases did, remove the particles of soot from the gas currents and the latter, as they issued from the chimney tops, were comparatively, if not wholly, free from those characteristics which constitute the smoke nuisance of to-day. The extracted soot was, moreover, not a waste product, but was utilised, in one instance at least, in the manufacture of an excellent quality of ink. At the present time, with smoke suppression as an absorbing topic in many localities, it would seem worth while to practically resurrect some of these old devices a little more frequently than is the case, for in a few places they are in service, in more or less modified and improved shape, and with apparently satisfactory results. The simple theory in the whole matter of smoke always has been that the best way to prevent it is not to make it, and it is along this line that intelligent inventive effort has, of late years, been expended. The fireman, too, as a smoke preventer or a smoke-making nuisance, has attracted attention, and the importance of his function is to-day tolerably well appreciated by most boiler owners. But, after all, there are in every manufacturing district furnaces which owners will not provide, except

under compulsion, with possibly expensive smoke-preventing equipment, in the shape of mechanical stokers, for example, however economical in final results, and to these the simple smoke washer, or absorber, did they but know of it, would be an acceptable means of helping to suppress the objectionable chimney discharges.

WHAT has more particularly prompted these lines is the recently published reference to a smoke-absorbing device installed at the boiler station of the South Kensington Museum, at London. Considerable annoyance had been caused there by soot and dust from the boiler house chimney, and the result was the recent installation of an apparatus invented by Colonel Dulier, from which relief was expected, and will, in all probability, be obtained. With this apparatus the products of combustion, before being permitted to enter the chimney, are taken up one leg of an inverted U-shaped flue, made of galvanised sheet iron, being assisted in their upward course by a steam jet. The latter assists also in the condensation of the tarry hydrocarbon products and saturates the dust with water vapour. In descending the second leg of the flue, the products of combustion are brought in contact with a large number of upwardy, inclined water sprays which are intended to thoroughly wash the smoke, moistening all particles of dust. The smoke and water next pass through a chamber containing a helical passage in which they are made to still further commingle, and after all this the gases are allowed to pass into the chimney proper, while the now sulphurous wash water is drained off. The draught in the flue and chimney, measured with a water gauge, is said to have shown no diminution after the erection of the apparatus. Just what the actual results are at South Kensington is not known at the time of writing, but tests with a similar equipment at Glasgow showed in one case a reduction of the soot in the gases from 73½ grains per 100 cubic feet before treatment to 2 grains after treatment; and in a second case, from 23.3 to 1.5 grains.

RECENT examples of drawbridge construction in the United States show that the disadvantages of this method of crossing navigable streams or inlets are at present being realised to their fullest extent. It is now a good many years since the competition between the great railway companies of Great Britain had the effect, first, of abolishing ferry links in the chain of transportation, and, second, of sending drawbridges of all kinds to join the defunct ferries. The rule for the English railway companies then became either high-level bridge or tunnel. High-level bridges were thrown across the Menai straits, the Frith of Tay, the Frith of Forth, the Tyne, and other navigable waters; while the Thames, the Mersey and the Severn were pierced by tunnels. These vast, and in most cases apparently unremunerative, engineering works were brought about to gain a saving in minutes, coupled with a thorough carriage between great cities. Fifteen minutes gain or loss in the five-hour run from Liverpool to London seems a small matter, but when a ferry trip across the Mersey to Birkenhead was added to the few minutes' delay in reaching London, the sensitive through-passenger traffic practically deserted one great railway system and gave its patronage to another. It must be remembered, in this connection, that English railways always agree to charge the same rates between competing passenger points, so that the railway which labours under any natural disadvantage has to make up for it, not by cheaper fares, but by increasing the frequency of its trains and generally improving its service. The tunnelling of the Mersey or the bridging of the Forth, therefore, instead of being a question of a few passenger fares more or less, becomes a policy upon which the future prosperity of the investing railway may depend. But, ferries being inadmissible for the reasons already

indicated, it may be asked why the English railway companies have shown such an antipathy to drawbridges. The answer to this is that all trains must slow down approaching a drawbridge, that the most important express trains are as likely to be delayed by its opening as the slowest freight trains, and—a matter which English railway companies always carefully consider—every drawbridge has in it the possibilities of an accident, the damages of which would pay the additional cost of a perfectly safe high-level bridge or tunnel.

Applying these remarks to the recent construction and equipment of drawbridges in the United States, we find that all the English objections to their use exist with even more force. Direct railway communication between the two largest cities in the country—New York and Chicago—and their respective contiguous territory is dependent upon drawbridges. During the heavy morning or evening suburban traffic in these cities, the opening and closing of a drawbridge, no matter how quickly accomplished, means the stalling of half-a-dozen trains. The elaborate derailment plans, with special signals and signal towers, attached to all the railway drawbridges in the United States, bear eloquent testimony to the well-grounded fear that the best human agency must sometimes fail in keeping the moving train out of the open draw. Moreover, as all navigable waters in the United States are under federal jurisdiction, while the land on either side is under the control of the respective States, the natural conflict of interests thus engendered has resulted in making the federal authorities keep open to navigation every third-rate ditch which has uninterrupted communication with some main system of waterways, especially if it be in the neighbourhood of a large city. Thus the railways, not having yet, except in a very few instances, decided that they must either tunnel or make high-level bridges near large cities, if they would give fast and uninterrupted passenger service, are compelled to rely on drawbridges.

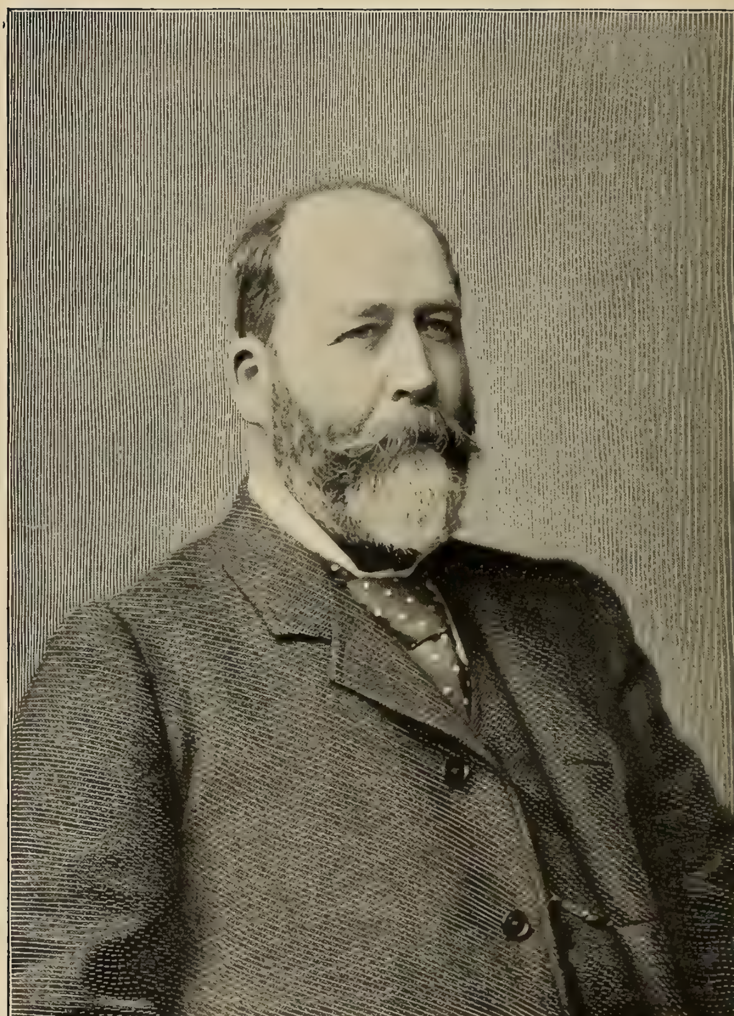
The type of drawbridge most commonly used is the deep steel lattice girder, balanced on a central pier, which is surmounted by a turntable drum. The width of clear channel which one of these drawbridges must expose when open varies from 50 to 200 feet. Probably the largest bridge of this kind was, until recently, the four-track structure belonging to the New York Central Railway crossing the Harlem river in New York City. The draw span is 400 feet long and 61 feet wide; when open, it gives two equal-sized channels of 165 feet each. In order that it may be opened and closed as quickly as possible, two fifty horse-power steam engines with oscillating cylinders are provided, and these are able to open or close it in two minutes. A much longer bridge of the same general type was opened a short time ago between Duluth and Superior. This bridge, or rather its swing span, is 493 feet long and 59 feet wide, providing double railroad tracks, double trolley tracks, ordinary roadways and footpaths. When this bridge is opened, it gives two clear channels of 200 feet each. Curiously enough, with the same horse-power as that of the great New York Central bridge, its span can be thrown open in considerably less time. The Duluth bridge, however, is worked by two fifty horse-power trolley street car motors, fed by an electric current brought from an adjoining power house by submarine cable through the middle of the revolving drum, and they regularly open or close the swing span in 1¼ minutes. In Chicago, where the river is comparatively narrow, a new form of drawbridge is rapidly coming into use. This is known as the Scherzer rolling lift bridge. It is of the bascule type, the leaves meeting in the centre when the bridge is closed and rising upright on opposite sides of the river when the draw is open. As these bascule bridges, while obviously unsuited for very long spans, require

no pier in the middle of the river, they are a distinct gain to navigation wherever they can be used.

SUCH bridges have two advantages, either for railroad or general use. One of these is that each leaf can be raised or lowered independently of the other so that time may often be saved in this manner. The other advantage is that when a leaf is up, it presents an impassable barrier to approaching trains or wagons. On this account it is well suited for an elevated railway where trains run on very short headway and the possibilities of forgetfulness on the part of the engineer in regard to an ordinary swing span are very great. It is to be noted that the Eads bridge over the Mississippi was built without any draw span, and that the cantilever bridge over the Hudson at Poughkeepsie—the only one below Albany—has no draw span, and as time goes on there is little doubt that the railway companies, acting in the public interest, will find means to have many of the so-called navigable inlets and rivers of to-day crossed with fixed bridges of moderate elevation, instead of cumbersome time-absorbing draw spans with which they are now equipped. There is something almost grotesque in the fact that the skipper of a fifth-rate tug boat has power at his pleasure to delay for ten minutes the entire through railway traffic of New York City, and a very large proportion of the through railway traffic of Chicago.

BUILDERS of mining machinery are ever confronted with the problem of transportation difficulties in mountainous countries. In North and South America particularly, Nature's obstacles to the carriage of unwieldy parts of mining outfits have taxed the resources of designers, with the effect of developing a species of "sectionalised" machinery in which every part, in point of weight and shape, has been proportioned with an eye to the carrying capacity of a mule. Engines, pumps and stamp batteries and the miscellaneous lot of other apparatus which make up the modern mining plant are all made in pieces, which, under ordinary conditions, would not be thought of and would entail useless detail in construction and subsequent erection. To the mine superintendent in almost inaccessible latitudes, however, they have a significance of the keenest interest and importance, and their proper consideration by the builder may make to the mine owner all the difference between smooth sailing and fretful delay and lost money.

APROPOS of this the *Engineering and Mining Journal* recently told of an incident communicated by a correspondent in Peru. A company operating there determined to erect a crushing mill, and the chief member of it, a German, insisted on placing the order in Germany. When the machinery, which had been specifically ordered for mule transportation, was unloaded, it was found to embrace timbers 16 by 24 inches, by 24 feet, weighing 800 pounds. This was destined to go by a trail which led over the *cordillera*, at an elevation of 16,000 feet to a *quebrada*, on the other side 7000 feet lower, over which no mule could carry more than 300 pounds, nor any piece longer than six feet. A similar case was reported from Mexico, where a stamp battery, timber and all, had been sent out from England. It was to be erected for an English company, and the order had been placed with a home manufacturer by the London office without consultation with the officers at the mine. The mine was ten freighting days from the railway terminus, without a vestige of a wagon road, and at last accounts the local officials were still puzzling their brains as to how the main battery frames were to be transported thither.



FROM A PHOTO. BY FREKE, CARDIFF.

Edw. P. Martin.

PRESIDENT OF THE IRON AND STEEL INSTITUTE.

CASSIER'S MAGAZINE.

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THE LARGEST STEAMSHIP AFLOAT.

By Gustav H. Schwab.

NO fact impresses the traveller more profoundly in passing through modern Germany than the marvellous growth which the industrial development of the Empire has attained. In travelling through the country it appears as if one could never pass out of sight of the factory chimneys. This development has manifested itself in all directions of industrial activity, but in no branch more strongly than in the shipbuilding industry, or rather in the construction of iron and steel steamships and of marine engines.

Twenty-five years ago no German steamship company would for a moment have considered the possibility of ordering their steamers built in German yards,—such was the lack of proper facilities for the construction of ocean-going steamships. To-day some of the best and most finished work in this line is being turned out in German yards. This result has been attained not by artificial means nor by navigation laws limiting German subjects to the construction of vessels in Germany; on the contrary, until a recent date the German steamship companies have had their vessels built in English yards.

Many hundreds of steamships were thus constructed in England for German account, but the painstaking thoroughgoing German shipbuilders, whose experience had been limited to the construction of wooden vessels, by repairing and renovating foreign-built steamers and by studying their construction in British yards, gradually became adepts in the art of steamship and marine engine construction. Beginning in a small way, their knowledge was increased and their experience enlarged, until, after successfully constructing freight steamers they entered the field, ten years or more ago, and made successful bids for the construction of ocean-going passenger steamships of large tonnage.

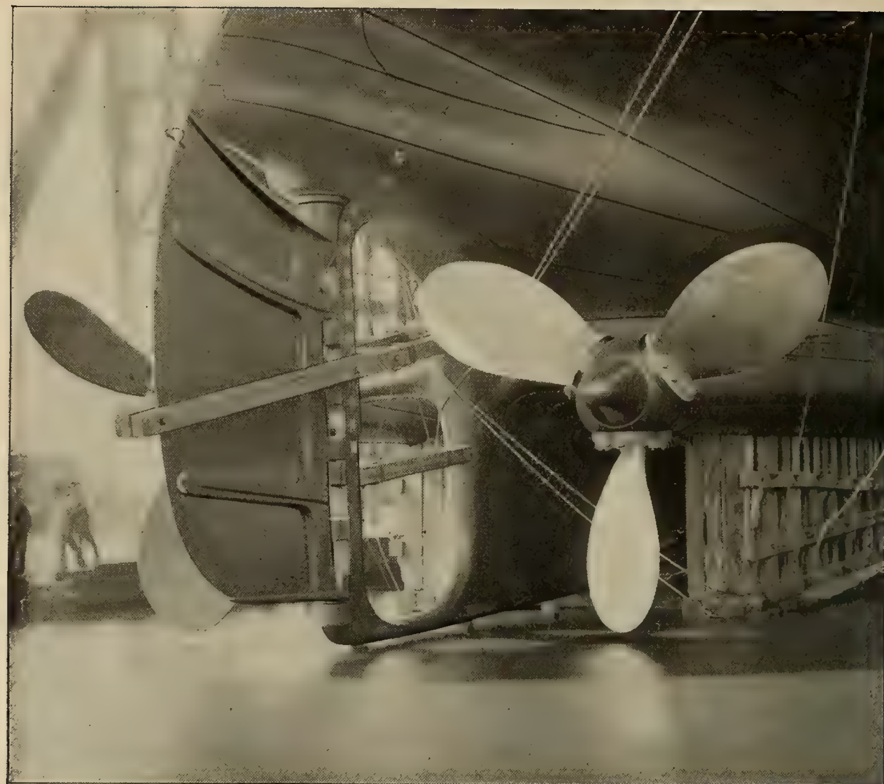
The successful efforts made by German shipbuilders were soon recognised by the leading steamship companies, especially by the Hamburg-American Line and the North German Lloyd S. S. Co., the result being that these companies have, for the last ten years, ordered most of their large vessels in German yards.

THE NEW NORTH GERMAN LLOYD TWIN SCREW EXPRESS STEAMSHIP "KAISER WILHELM DER GROSSE." LENGTH, 648 FEET. BREADTH, 66 FEET. TONNAGE, 14,000. INDICATED HORSE-POWER, 28,000. BUILT BY THE VULCAN SHIPBUILDING COMPANY, STETTIN, GERMANY.

The latest product of German shipbuilding skill is the giant steamship *Kaiser Wilhelm der Grosse*, which was recently placed in the express service of the North German Lloyd, between Bremen and New York. The keel of this steamship was laid in the yards of the Vulcan Shipbuilding Company, at Stettin, at the end of the year 1895. She was launched on May 4 of last year and made her first trip from Bremen to New York on September 19, 1897. On this maiden trip she exceeded the record made by any other steamship on her first trip, covering the distance from Southampton to New York,—3050 miles,—in 5 days, 22 hours and 35 minutes, at an average speed of 21.39 nautical miles an hour. On the return trip of her maiden round trip she covered the distance from New York to Eddystone Light,—2962 miles,—in 5 days, 15 hours and 10 minutes, at an average speed of 21.91 nautical miles an hour. On both of these trips, westbound and eastbound, she made the best time between New York and the English Channel. During her first trip, after dropping her pilot, her engines were not stopped until the pilot was taken on board off Sandy Hook Lightship. These results speak most eloquently for the skill with which this giant vessel was built.

ONE OF THE DECK PROMENADES.

The dimensions of the *Kaiser Wilhelm der Grosse* are as follows:—Length



A VIEW OF THE BRONZE TWIN PROPELLERS. DIAMETER, 22 FEET 3 INCHES.

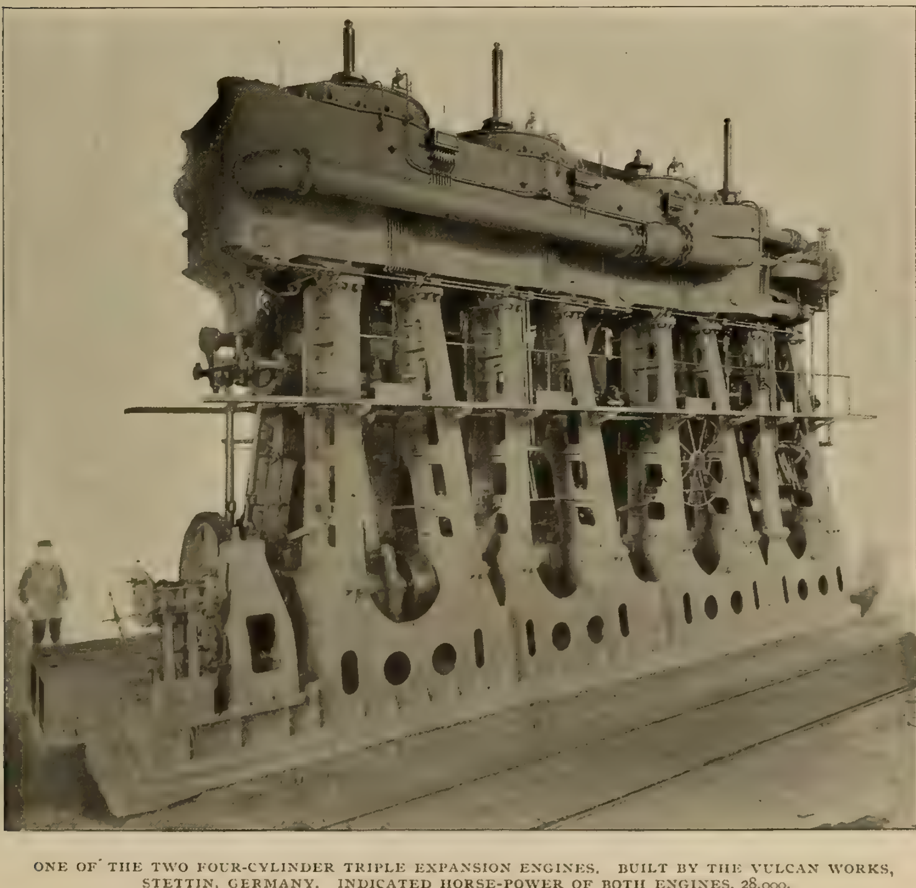
over all, 648 feet; beam, 66 feet; depth, 43 feet; tonnage, 14,000; and displacement, 20,000 tons. These measurements exceed those of all vessels of other nations, and the *Kaiser Wilhelm der Grosse* can therefore justly claim the title of the largest vessel in the world. Her yacht-like lines and her great sheer give her a graceful appearance on the water, and she has been proven, by experience gathered on her first two trips, to be a very comfortable sea vessel; her great length does away with most of the pitching motion, while her sheer forward makes her a dry vessel. The rolling motion is, to a certain extent, prevented by the attachment of bilge keels. A further boon to the travelling public is the prevention of the violent vibrations so often created on ocean steamers by great engine power. The two engines with their four cylinders have been so well balanced by a system invented by the German engineer Otto Schlick, that in the dining room and staterooms, as well as on the promenade deck, the engine vibrations are hardly perceptible.

The first element to be considered in the construction of a modern passenger steamship is undoubtedly that of safety. The comparative immunity from disaster which has attended transatlantic passenger traffic during the last ten years is testimony to the advance made in safety appliances in all first-class steamships. The hull of the *Kaiser Wilhelm der Grosse* is divided by sixteen strong transverse steel bulkheads. These all extend to the upper deck. The two engines are separated by one longitudinal bulkhead running through the engine room. Thus the entire hull is divided into eighteen water-tight compartments which are so arranged that no two large compart-

ments immediately adjoin. The large compartments are separated by small ones in such way that no two large compartments can be filled at the same time; but should three compartments fill, the steamer would still be prevented from sinking.

The boilers are divided into four groups, each of which is placed in a separate water-tight compartment entirely cut off from the others, so that in case of an accident involving damage to one set of boilers, the vessel would never be without steam to work her main engines or her pumps. Besides this division the vessel is provided with a double bottom, the inner skin being four feet from the outer one. In this double bottom, which is intended to protect the vessel from serious injury in case of running aground, the water tanks are arranged in which water ballast is carried. These tanks have a capacity of about 2100 tons of water and are used for the purpose of replacing the weight of coal taken out of the steamer during the voyage. In addition to the safety appliances thus provided for, the ship carries twenty-four large life boats on the awning deck, in davits, ready for immediate use. On the decks of the steamer emplacements have been built for cannon, as the *Kaiser Wilhelm der Grosse* has been constructed throughout in accordance with the requirements of the Imperial German Admiralty, and will be called upon in case of war to enter the German naval service as a cruiser.

Turning now to the motive power



ONE OF THE TWO FOUR-CYLINDER TRIPLE EXPANSION ENGINES. BUILT BY THE VULCAN WORKS, STETTIN, GERMANY. INDICATED HORSE-POWER OF BOTH ENGINES, 28,000.

THE FIRST-CABIN DINING ROOM.

that drives this enormous vessel, we find the steam required by the engines generated in twelve double-ended and two single-ended boilers, which weigh 1850 tons when filled with the water that they require. There are 104 furnaces, measuring 6 feet by 3 feet 10 inches, and containing a grate area of 2392 square feet. From each of the four groups of boilers a smokestack, 12 feet in diameter, ascends to 110 feet above the keel. Each boiler compartment is provided with a separate steam feed pump, and from each boiler an 18-inch main steam pipe carries the steam to the engines.

The two engines are of the triple-expansion type, each working on four cranks with four steam cylinders, one behind the other. They were built by the Vulcan Shipbuilding Company, the builders of the hull. The diameters of the cylinders are as follows:—high pressure cylinder, 52 inches; intermediate cylinder, 89¾ inches; two low pressure cylinders, 96½ inches.

These engines turn nickel-steel shafts constructed by Krupp, of Essen, Germany, 24 inches in diameter, which are bored out to a diameter of 5 inches to ensure against imperfections in the metal and to enable a thorough inspection of the interior of the shafts. The shafts are built in the side of the vessel, and at the end of the shafting, 198 feet in length, the three-bladed screws revolve, measuring 22 feet 3¾ inches in diameter, with a pitch of 32 feet 10 inches. They are made of bronze and weigh 26 tons each. The screws revolve at from 75 to 80 turns a minute. The engines measure 42 feet in height from their foundations to the top of the cylinders. The two condensers have a cooling surface of 35,522 square feet, and the tubes in the condensers are 11,060 in number, having a combined length of 35 miles.

For the various other purposes needed on the steamer, pumps and auxiliary engines to the number of 66 are provided. These comprise feed pumps, bilge pumps, air pumps, centrifugal pumps, refrigerator pump, dy-

namo engines, hoisting engines and steering engines, with a total of 124 cylinders. For the purpose of ridding the vessel of water, four centrifugal pumps, two engine pumps and six duplex pumps are available, capable of handling a total of 3600 tons of water per hour.

The total force in the engineers' department comprises 216 men, of whom the stokers and coal heavers number 180, working in three watches of four hours each. The engineers' watches are two of six hours each.

The boiler room is ventilated by natural means, and artificially by sixteen ventilating fans. Besides the 400 tons of fresh water, used for cooking, drinking and washing purposes, and which are equal to 107,405 gallons, the steamer carries 240 tons of fresh water for the boiler, the loss of which is replaced by evaporators with a capacity of 80 tons of fresh water a day.

The question of disposing of the ashes was in former years a source of frequent annoyance to passengers. The ashes were generally disposed of by hoisting them to the upper deck, from which they were dumped over the side of the vessel. The noise of the ash hoists and the emptying of the large cans rendered the rooms on that side of the vessel on which this operation was performed most disagreeable and unpleasant. All this nuisance has been abated by the invention of an American engineer, Mr. Horace See, by which

ON THE UPPER ENGINE PLATFORM.

A CORNER IN THE SMOKING ROOM.

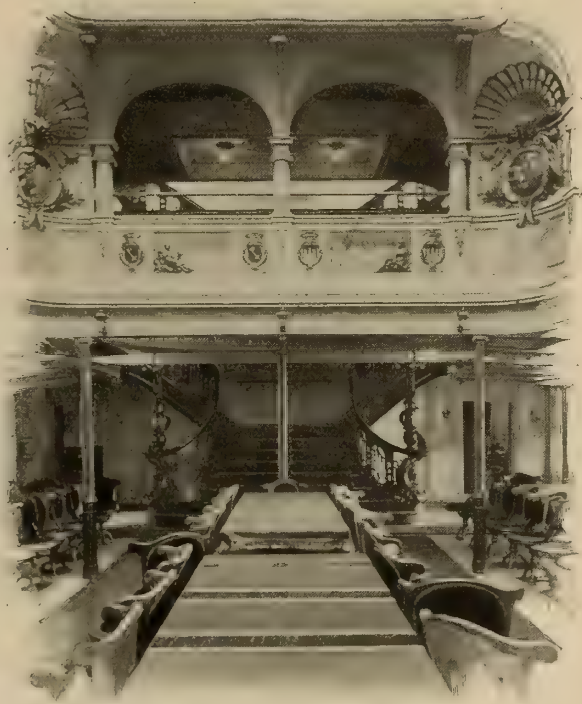
THE GALLERY ABOVE THE DINING ROOM.

the ashes, mingled with water, are ejected by a powerful pump directly from the fire rooms through a tube above the water line, doing away entirely with the former hoisting and handling on the upper decks.

The great size of the vessel made it necessary to bestow special thought on the arrangement of the space for the officers and crew in order to secure for passengers the greatest possible comfort and to place the ship's servants where they would not inconvenience passengers. For this reason the steerage passengers have been placed in the forward part of the vessel, entirely separated from the amidships portion, which is occupied by the first-cabin passengers, and they, in their turn, are separated from the after part of the steamer, where the second-cabin passengers are placed. The captain and officers are located on the bridge deck, immediately under and aft of the bridge. The engineering force is quartered immediately in the vicinity and around the engine rooms, and the sailors are placed in the forecastle.

The bridge, from which the management of the steamer proceeds, just as the human body is directed from the brain, is placed immediately over the captain's apartment and, running across from side to side of the steamer, overhangs each side by about four feet. In the middle and at the ends of the bridge are shelters constructed of steel with large, thick plate-glass windows behind which the officers are able to take their position to protect themselves against rain or flying spray. To the rear of the centre of the bridge is the wheel house, an enclosed structure in which the small wheel is placed, which actuates a piston in a hydraulic cylinder and brings pressure to bear through a small pipe filled with glycerine to the mechanism of the steering engine, which is installed below the water line aft and immediately above the rudder.

To provide for the possibility of damage to the forward wheel house, a reserve pilot house is established over the deck house of the second-cabin aft which is equipped with a duplicate hydraulic steering gear. There are also in the centre of the forward bridge, protected by the shelter there, telegraphs and telephones leading to both engine rooms as well as to the after bridge.



AT THE FOOT OF THE DINING ROOM STAIR WAY.

These telephones are so constructed that the sound transmitted by them is audible at a distance of thirty feet from the telephone receiver. In the wheel house on the forward bridge an ingenious electric annunciator shows the position in which each water tight door is in each bulkhead on the steamer, by small disks which are thrown in place as soon as the corresponding water tight door is closed. The captain can

ANOTHER VIEW OF THE "KAISER WILHELM DER GROSSE."

communicate from the bridge to every compartment door and can thus control the closing of these doors and can count the time needed to carry out the orders to close. The doors are closed as a matter of practice once each day at a different hour; the time in which the order has been carried out has generally been about fifteen seconds.

The deck structure of the *Kaiser Wilhelm der Grosse* differs materially from that of other large modern steamships. Instead of open gangways on both sides of the upper deck, exposed to a certain extent to the weather, such as are found on all other fast twin-screw passenger steamers, the North German Lloyd, in arranging the upper deck construction of this ship, have placed the rooms on the upper deck immediately at the sides of the vessel, the gangways running on the inner side of these rooms.

Another radical departure from the ordinary construction has been made in the location of the large majority of the staterooms on the upper and promenade decks. This contributes materially to the comfort of the cabin passengers, as they are berthed on the upper decks where no bulkheads hinder the ventilation and the easy access of passengers from one part of the vessel to the other, and where, the rooms being situated high above the water, they can keep their port holes open in almost any kind of weather. The bulkheads

separating the various compartments of the steamer can thus be kept entirely closed at night and in foggy weather without inflicting any discomfort upon passengers. The best portion of the steamer, on the upper deck and on the promenade deck amidships, is thus devoted to the use of first-cabin passengers.

The large dining room is situated exactly amidships on the main deck between the two sets of smoke stacks, in a position in which its occupants are least affected by the motion of the steamer. Forward of the dining room are toilet rooms and bath rooms for men on the port side, and the same apartments for women on the starboard side. Forward of these are a number of first-class staterooms with a small children's dining room, access to which can be had by a staircase directly to the upper deck.

The dining room extends from side to side of the steamer and contains tables running lengthwise, as well as small tables crosswise in alcoves at the sides of the steamer. In the centre of the dining room a large skylight of majestic proportions leads upward to the decks above. The decoration of the dining room is entirely in white with representations, in relief, of German cities in the panels of the skylight. Paintings in subdued colours decorate the walls, comfortable sofas are spread in the alcoves, and over the parquet floor rugs are laid. The dining room itself is nine feet in height and well proportioned, and its coloured portières and table covers contrast agreeably with the tints of the walls.

THE FIRST-CABIN DRAWING ROOM.

At both ends of the large dining room there are, on each side, four smaller dining rooms, connected with the principal room, but kept entirely separate and used for the accommodation of smaller parties. These four small dining rooms bear the names of the mother of

A LIBRARY CORNER.

ANOTHER VIEW OF THE DRAWING ROOM

the Great Emperor, of his consort, and of Prince Bismarck and Count Moltke. The style of these rooms is different. The Bismarck room is decorated in rococco, in dark tones and walnut; the Queen Luise and Empress Augusta rooms are in Italian Renaissance, and the Moltke room is in Queen Anne style. The last three rooms contain pictorial representations, descriptive of the life and history of these personages.

In the main dining room, with its four side rooms, about 400 persons can easily dine at once. Aft of the dining room is a commodious pantry, running from side to side of the steamer, and containing every device for the serving of meals. Aft of the pantry is the large kitchen, with tiled floor, and a circular range, provided with a hood and artificial exhaust draft to carry off the fumes of cooking. Sculleries and other spaces are attached to the kitchen, aft of which on this deck we come to the engine rooms and the quarters of the engineering force around them.

From the large dining room a wide staircase leads up to the next deck on which an extensive vestibule or hallway, surrounding the dining room skylight, offers a convenient gathering place and promenade in bad weather. From this vestibule a view is had through the arched openings in the skylight of the dining room. The walls of the vestibule are artistically treated and the comfort of the space is enhanced by carpets, easy chairs and sofas. The staterooms open into the vestibule through small gangways, and passageways, extending aft and forward from the vestibule, communicate with other parts of the steamer.

On the promenade deck above this vestibule is placed the drawing room, a high and well-ventilated apartment of generous dimensions built around the cabin skylight and lighted by large square windows opening to the promenade deck on either side. The walls of this room are decorated with rich brocade and are surmounted by a plastic frieze with portraits of the best known poets and musicians of all nations. The central attractive feature of this drawing room is a life size painting of His Majesty, Emperor William I., representing the emperor with crown and sceptre. A grand piano adds to the features of the room and easy chairs and sofas are distributed through it.

The drawing room opens aft into the upper vestibule on the promenade deck, from which a grand staircase leads down to the lower vestibule and dining room. Wide gangways lead from this vestibule aft to the smoking room, which is one of the most attractive apartments on the steamer. Its height and excellent ventilation through two large skylights make it an exceedingly pleasant sojourning place for the male passengers. It is decorated in light coloured oak in the style termed early German Renaissance, and is provided with alcoves and seats and sofas upholstered in raised leather. Its light is received through large square side windows opening on the promenade deck, and through the skylights.

ONE OF THE FOUR CHAMBRES DE LUXE.

Aft of the smoking room is a collection of staterooms on the promenade deck, communicating by passageways under shelter with the rest of the steamer. Forward from the drawing room is the library, a beautiful room, decorated in rococco with Gobelin tapestry and walnut, and containing a large assortment of international litera-

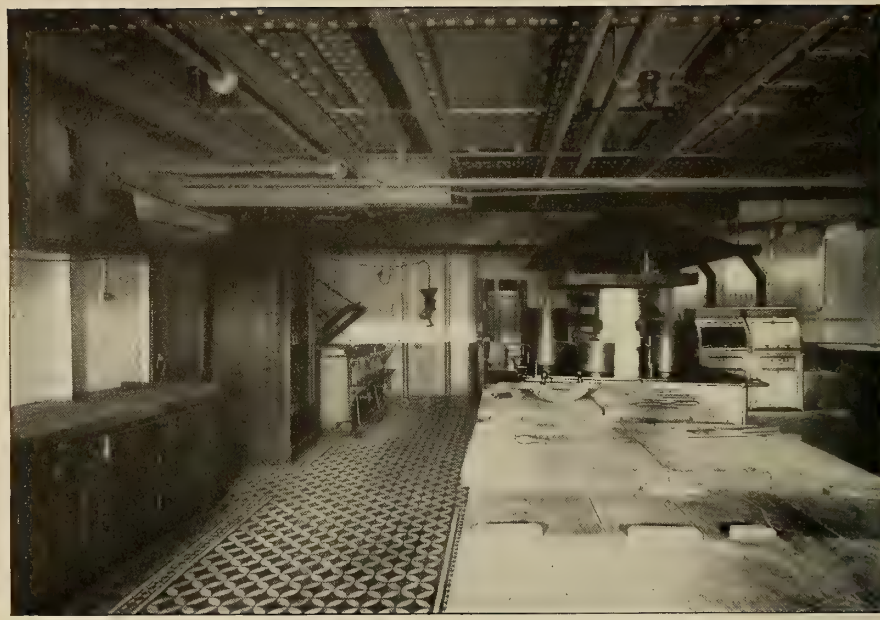
THE LIBRARY,

ture, disposed in bookcases. This room is provided with easy chairs, sofas and six large double writing tables. Between the drawing room and the library are situated the four "cabines de luxe" on the promenade deck, opening on to the corridor from the drawing room to the library. Each of these apartments consists of an attractive sitting room with tables, sofas and chairs, and a large bedroom with a brass bed and a bathroom with tiled floor. There are, besides these "cabines de luxe," single staterooms of large dimensions adjoining the cabines de luxe on this deck.

Descending from the promenade deck to the upper deck we find there the large majority of the first-cabin staterooms, running from the engines forward and therefore amidships, in that position in which the passengers are least exposed to the ship's motion. It is well to compare the luxurious staterooms on this steamer with the accommodations provided on the first trans-Atlantic steamers forty years ago. Those who then crossed the ocean will appreciate the advance that has been made, not only in the motive power and the size of the steamers, but also in the arrangements made for the comfort and well-being of the traveller on his way across the stormy ocean. Many of the staterooms on the *Kaiser Wilhelm der Grosse* are so arranged as to be convertible into sitting rooms during the daytime, on the same plan as the staterooms on railway sleeping cars, with the only exception that the steamer staterooms are considerably larger. Not only in point of length and breadth do these rooms distinguish themselves as compared with the size of the rooms

THE FIRST-CABIN PANTRY.

in the first period of trans-Atlantic ocean travel, but in point of height, which is about nine feet from deck to deck, ensuring greater comfort and better ventilation. There are more than 200 staterooms provided for the use of first-cabin passengers on this steamer, offering accommodation for about 400 people. Another improvement introduced on the *Kaiser Wilhelm der Grosse* is the provision of a number of rooms for one passenger only, a convenience that commends itself to many.



A KITCHEN VIEW.

Returning to the promenade deck, on which the deck houses containing the library, drawing room, smoking room and the sets of staterooms on that deck open, we find a promenade on each side of the steamer, about 400 feet in length, protected by an awning deck from rain or spray. This awning deck is so constructed that it also affords a pleasant promenade and lounging place for passengers during fine weather.

Accommodation for the second-cabin passengers is found aft of the engine room, where, on the upper deck, main deck and the deck below, 100 rooms are placed, berthing about 370 persons. The larger number of these rooms are situated on the upper deck and a number of them are arranged for two persons only. The second-cabin dining room, extending from side to side of the vessel, is situated on the main deck immediately aft of the engine hatch and is furnished in polished walnut. A second, smaller, dining room is situated on the upper deck, and on the promenade deck there is a deck house which contains a spacious smoking room. The entire after part of the deck of the steamer as well as the deck of the deck house is placed at the disposal of the second-cabin passengers.

The toilet and bathing arrangements on the steamer are adapted to the needs of the large number of passengers carried. Besides the four bathrooms belonging to the "cabines de luxe," there are fourteen large bathrooms for first-cabin passengers, with nickel tubs and douches, distributed throughout the steamer, while the second-cabin passengers have six bathrooms at their disposal.

The steerage passengers are accommodated in the forward part of the vessel in two compartments of the main deck and four compartments of the lower deck, with accommodations for 800 people, whose quarters are furnished with iron beds, tables and benches. The steerage contains also four large hospitals with two bathrooms and toilet rooms.

The lighting of the steamer is entirely by electricity. There are 1600 incandescent lights of 25-candle power each, supplied by four large dynamos in the after part of the vessel. Electricity is

also used in the green and red side-lights and the top lights of the steamer.

The provision rooms for cabin passengers are situated amidships, aft of the engine room, and contain four large refrigerating rooms, kept at a proper temperature by an ice machine, besides other storage rooms. The provisions are hoisted from these rooms by an electric elevator to the first and second-cabin kitchens, which are situated above them. The provision rooms are supplemented by small refrigerators and dressers in large numbers contained in the pantries.

It may be of some interest to consider, in connection with the description of the provision rooms, the quantities consumed on the *Kaiser Wilhelm der Grosse* on one trip. Of fresh meat and fish 17,000 pounds are used; of game and poultry 4400 pounds; 14,000 eggs; 8000 oysters; 300 pounds of lobster; 1600 pounds of cheese; and 280 barrels of flour from which fresh bread is baked every night in two large baking ovens; 2400 pounds of fresh fruit; 9000 oranges; 4000 lemons; besides fresh vegetables and all sorts of salt, smoked and preserved fish and meat as well as large quantities of various delicacies.

The provision room for steerage passengers is situated in the forward part of the vessel and contains a cellar, cooled by ice, and communicating by elevator with the steerage kitchen, which is situated under the forecastle and is provided with five large boilers for steam cooking.

The success of the Vulcan Shipbuilding Company in turning out this latest marvel of ship construction has drawn forth the encomiums of all those students of the art of shipbuilding who have had an opportunity to examine the steamer, and the prediction is freely made that the record so far established by this new competitor for the world's honour will be still further lowered. May she justify this prediction and may her career be a prosperous and a profitable one!

A CABLEWAY ERECTED BY THE BROWN HOISTING AND CONVEYING MACHINE CO., CLEVELAND, O.

AMERICAN CABLEWAYS IN OPEN-PIT MINING.

By Spencer Miller, Mem. Am. Soc. C. E.

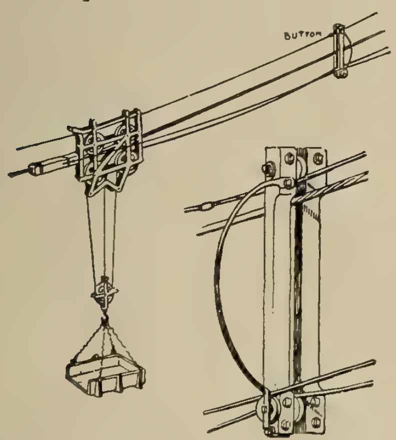
THE problem of open-pit mining, whether the mineral to be mined be coal, iron, phosphate, copper, gold or zinc, consists, to begin with, in the removal of the overburden. This is usually a waste product and must be taken off at the lowest cost per ton, and the value of the appliance applicable for work of this sort depends largely upon the character of the ground to be stripped. After this, comes the removal of the ore and waste.

The advantages which would be derived from a machine to hoist and convey loads, using a suspended cable as a trackway, have been appreciated by engineers for a hundred years or more, but it has remained for the last few years to see any practical development of such a machine, and the modern cableway stands to-day as the result of such development.

The first practical form of cableway was put into use about 1860 in the slate quarries of Pennsylvania, in the United States. It consisted of a cable suspended on an incline of about twenty-five degrees, a cable carriage operated on this cable, a fall block, adapted to rise and fall from the cable carriage, and a hoist rope, which performed the double function of hoisting the load to the carriage, and conveying the carriage up the inclined cable. These cableways fitted the particular conditions that existed in the slate quarries so perfectly that they were frequently duplicated, and are still to be found in that region with very little improvement.

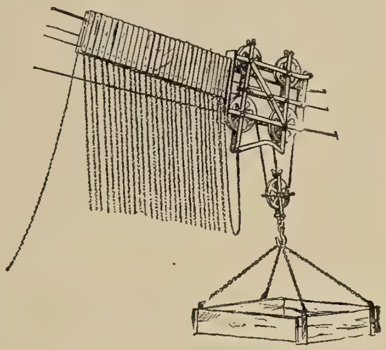
The next form of cableway was one in which the main cable was suspended practically horizontally. The carriage in this event was moved back and forth

by the use of an endless rope operated by a drum, being a part of the hoisting engine. Another drum performed the function of hoisting. Such a machine was first introduced for open-pit mining at the Tilly Foster mine, in New York. The reason for the adoption of the cableway was that a derrick could not be constructed with sufficient reach to hoist and deliver the material from the pit. The problem at the Tilly Foster mine was to convert the old mine into an open pit by the removal of something like 300,000 cubic yards of rock. It was calculated that this would uncover at least 600,000 tons of ore. This excavation was something like 450 feet long by 300 feet wide. It was quite imperative that a skip load of material should be lifted up directly at the place where it might be filled, and it was therefore necessary to use a hoisting and conveying device, which would reach out further than it would be practicable to use a derrick.



AN EARLY FORM OF BUTTON ROPE FALL ROPE CARRIER.

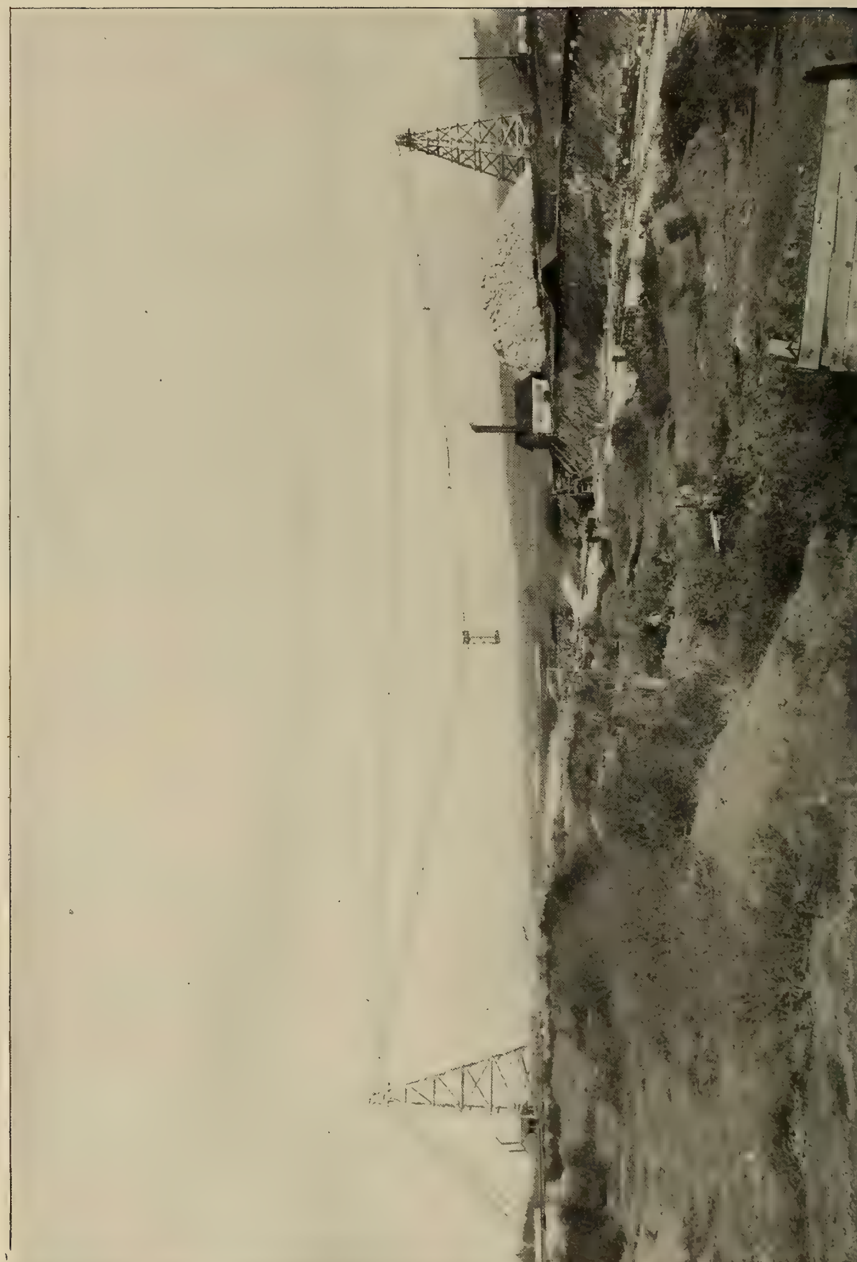
At that time, about 1888, the cableway was in a crude state of development, but in spite of this, it was found to be by far the most practical device that could be used for that purpose. The plant, as originally installed, consisted of four cableways and a large derrick, with a 110-foot boom. The cableways were much preferred to the derrick and by them practically all the work was done. It was found by actual records that the cableway would take out ten per cent. more loads per day than the derrick, in spite of the fact that it was reaching out about 300 feet, while the derrick, on the other hand, could reach out only 110 feet.


CHAIN-CONNECTED FALL ROPE CARRIERS.

Similiar engines were used for hoisting the load in each case, and a separate steam engine was used for swinging the derrick. The comparison made was between a crude cableway and a derrick of the most modern type at that time, the latter operated by a high-speed engine, and swung by steam. Recent improvements in cableways would probably make a still more favourable showing for the cableway,—possibly 25 per cent.

On this plant chain-connected fall rope carriers were used to support the hoist rope between the towers and the carriage, which consisted of a series of blocks, with 8- or 10-inch wheels to run on the main cable, spaced about every fifty feet, connected with one inch chains. These heavy and cumbersome fall-rope carriers were the source of much annoyance. The weight of chain and carriers used on this plant was about a ton. The chains swing about and get entangled in the fall block, and with one another; they limit the speed, and wear the cable.

Long and high-speed cableways were not practicable with the chain-connected fall rope carriers. The lower illustration on this page shows the first departure and represents the beginning of a development in the line of improved fall rope carriers. An auxiliary rope,



ONE OF THE CABLEWAYS USED ON THE CHICAGO DRAINAGE CANAL, BUILT BY THE LIDGERWOOD MFG. CO., NEW YORK.

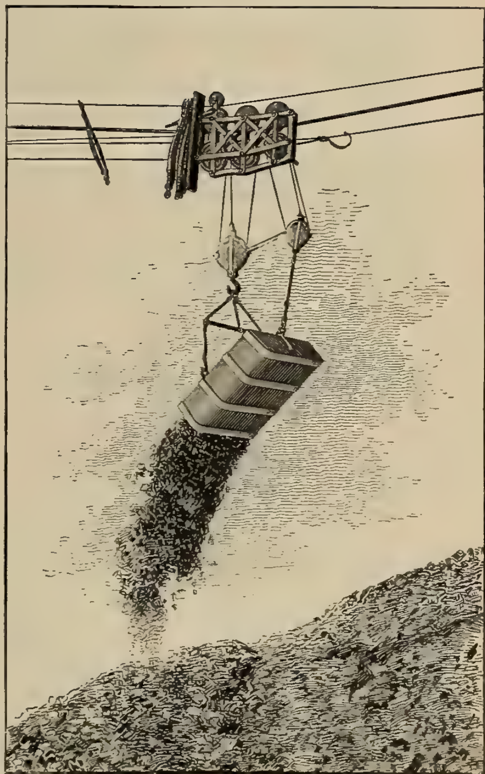
about ⅝-inch in diameter, is suspended above the main cable, held in a parallel position to the main cable, by passing under wheels in the cable carriage. On this rope a series of buttons are secured, whose diameter increases with the distance from the head tower. Slots in the head of the carriers, corresponding to the diameter of the buttons, allow each of the carriers in passing down the incline to be stopped at its proper button. These carriers have small wheels to roll on the auxiliary or button rope. Thus, the heavy cumbersome chains are dispensed with, and these fall rope carriers, spaced by buttons, and weighing about 100 pounds, answer all the requirements of chain-connected carriers, weighing, with the chain, 2000 pounds, causing an increased strain on the anchorage of about 5 tons.

The cableway in a more perfected form was extensively employed in phosphate mining in Florida, and while the form of cableway there employed was the most modern at the time of its installation, and while it was considered the most economical device for use in phosphate mining, still the travelling cableways, as used on the Chicago Drainage Canal, would have been found of still greater value. In fact, were it not for the great depression in phosphate mining during the last few years, many such installations would probably have been made.

The most prominent example of the use of the cableway for phosphate mining is in use by the Dunellon Phosphate Company, at Dunellon, Fla.

The developments which have been made since the time of this installation have been in the direction of increasing the capacity of the cableway by increasing the number of trips per day. This has been largely accomplished by the use of the device known as the aerial dump, whereby the act of delivering the load from the skip is done automatically by the moving of a lever by the engine man, so that the load may be automatically delivered at any point desired. This not only saves a man for releasing the load, but it also largely reduces the time required for dumping the load. A further improvement, namely, that of making the entire machine movable, has brought the cableway up to a position where it practically becomes a long-distance travelling crane.

In one of the iron ore mines in the Lake Superior region the experiment was tried of remodelling one of the modern cableways so as to operate a self-filling grab bucket. The experiment was partially a success. It required, however, some very material modifications to the machine in order that the operation should be entirely successful. At the present time that feature has been made an entire success, as evidenced by a new installation put in for the St. Paul Sand Company, at St. Paul, Mo.



AERIAL DUMPING.

Here a cableway, practically horizontal, with all the modern improve-

A HEAD TOWER AND ANCHORAGE MOUNTED ON WHEELS.

ments of high speed and simplicity, has been installed, and, in conjunction with the use of a self-filling grab bucket, has been successfully operated. It is in daily operation, excavating sand and gravel from the bed of a river 30 feet below water, filling itself, hoisting, conveying, and delivering to the hopper for the sand bin where the material, passing through screens, is separated into its various grades and is shipped away for merchantable purposes. This machine is worthy of description, inasmuch as it represents one of the most modern labour-saving improvements as applied to the modern cableway.

This plant has, by actual count, made 33 trips in 44 minutes. It averages, however, from 30 to 40 trips per hour, or from 300 to 400 trips per day of 10 hours. The bucket has a capacity of one and a half yards. The amount of material actually delivered is 18 car loads per day, averaging 18 yards per car, bringing the total up to 324 cubic yards. To deliver this amount of material to the bins requires a labour force of

An engineer	\$2.50
A fireman	1.50
A signal man	1.25
Fuel (say)	2.00
Oil	.25
	\$7.50

making a cost of \$7.50 per day. Estimating 300 cubic yards as the daily capacity, it will be seen that the actual operating cost is about 2½ cents per yard. Of course, this does not include any labour force about the screens, nor does it include the wages of a foreman, nor any repairs, which, while slight, still must be considered as an item of cost.

A similar plant was installed for the Pacific Red Gravel Company, the capacity of which is still greater. Their plant handled 11 cars in 3½ hours, or at the rate of nearly 600 cubic yards per day. The capacity of one of these cableways may, therefore, be said to vary from 300 to 600 cubic yards per day, in accordance with the circumstances.

Another interesting form of cable-

way, which has recently been developed, was installed for experimental purposes in Michigan for mining fire-clay. This particular installation had the most difficult material to handle, as well as the light loam on the surface. In this installation the cableway is made with travelling towers. The span was short, but was sufficient to determine the experiment to be solved. A peculiar form of bucket, known as the drag bucket, was used for digging this material.

In the operation of this machine, the bucket was hoisted and carried over the point where the material was to be dug. The bucket was then lowered to the ground, where it automatically settled into a position favourable for digging. The carriage was then run forward, leaving the bucket on the ground. When the direction of the ropes leading from the carriage to the bucket was favourable, the hoisting line was hauled in and the bucket dragged along the ground; the teeth of the bucket would then plow into and cut their way through the clay or dirt and the bucket was completely filled. It was then hoisted and conveyed back to the point of delivery, where it was automatically dumped or overturned, and the material delivered to the car, or to the waste pile, in accordance with the class of material dug. The experiments were carried on at a great expense, and the bucket was modified a great many times, until the plant was brought to a point where the hardest clay found in the neighbourhood was successfully excavated without the aid of any man, excepting the engineman and fireman.

A cableway built on this plan was recently installed in Montana. The bucket was pronounced to be a perfect digging machine. In this plant the head tower was made stationary and the tail tower was made portable, travelling on a circular track about the head tower as a centre.

The advantages of open-pit mining have been dwelt upon to such an extent that no argument will be made in defence of the plan. The annoyance incident to underground mining, where the excessive cost has to be met of timbering, shaft sinking, pumping, of the largely increased cost of breaking the ore (this one point sometimes makes a saving of 80 per cent.), the extra cost of blasting, make the idea of open-pit mining extremely popular. It has been

A TRAVELLING CABLEWAY WITH DRAG BUCKET DIGGING CLAY.

A ROPE TRAMWAY AT THE GOLD KING MINE IN COLORADO, INSTALLED BY THE TRENTON IRON CO., TRENTON, N. J.

said that the limit to which the removal of the overburden becomes profitable is put at four cubic yards of overburden for every ton of ore laid bare. This may be modified by the very great improvements made in the machinery for open-pit mining, in rock drilling, and the methods of blasting.

The cost of removing the overburden varies much with the nature of the ground, especially with reference to the point of dumping the waste. It is frequently the case that a cableway may be applied in such a way as to span the opening, and carry back the waste to a depression, so that the overburden may be delivered directly to its dumping ground. This is especially the case with phosphate mines in Florida. There the country lies practically level, and the phosphate beds may frequently be stripped by using a travelling cableway, spanning both the pit and the dumping ground, the material taken from the pit being delivered at a point directly opposite the point from which it is taken.

The cableway must also be considered as superior to any method of working with incline planes, as is frequently done where the pit is shallow. In whatever way the incline railways are put in, or railways in the bottom of the mine, they are sure to cover over a certain amount of ore. A blast is certain to throw considerable material on the tracks, the cost of removing which must be considerable.

The cost of loading the material into the shallow skips used on the cableway makes a very appreciable saving over the cost of loading into cars. The records of the Chicago Drainage Canal show that while labourers, sledging and filling into cars, averaged only 7 to 8½ cubic yards per man per day, in filling into skips for the cableways, the labourers averaged from 12 to 17 cubic yards per day. The extraordinary difference, however, made on the Chicago Drainage Canal would not be so great, were it not for the fact that considerable of the stone on the canal had to be sledged before it was small enough to be lifted into the cars. In mining operations where the material breaks up easily under the hammer, this difference would not be so marked. Take for example asbestos mining at the Beaver Asbestos Mine, at Thetford, P. Q.; 225 tons per day of material were handled with seven muckers, and at a daily cost for labour for filling the skips, engineman and fuel, and all

A DRAG BUCKET.

the cost of mining and delivering, of $12.35, making 5½ cents per ton.

The cableway has also been recently applied for stripping coal mines in Pennsylvania. A. S. Van Wickle has adopted the cableway system for the Coleraine Colliery, at Beaver Meadow, Pa. The span of this cableway is 1000 feet, built for handling seven-ton loads. The plant is operated with a 50 horse-power reversible link-motion engine,

A BUCKET FILLING.

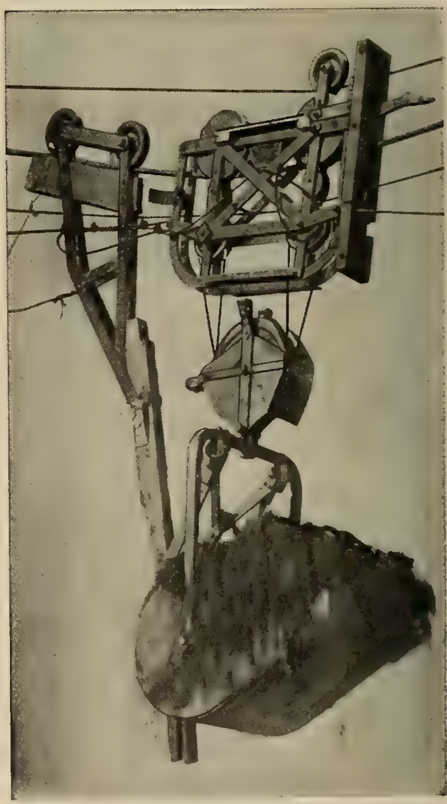
with 54-inch drums, and a head tower 100 feet high.

J. W. Worthington & Co., of Birmingham, Ala., have recently erected two cableways, one for handling rock from the quarry to the crusher, and the other for handling iron ore. The latter hoists and conveys the iron ore, which is in a thin layer near the surface, from the mine to the crusher. Both cableways were also employed for stripping off the top layer of earth and other refuse. The span of each cableway is 900 feet and the load handled, six tons. This is an entirely new departure for mining and quarrying in that section of the country.

One of the most interesting cableways that has ever been built is the one which was used for cleaning up the dirt filling of the new Drainage Canal for the City of Mexico. This canal was dug with enormous hydraulic dredges, and after the work had been practically completed, it was found necessary to go over the work again to dig out the dirt which had been washed in from the sides. To do this work, a travelling cableway of about 350 feet span was installed. Its towers were mounted on movable cars, in the same manner as that of the travelling cableway at Chicago. A self-filling grab bucket of the orange-peel type was used for digging, hoisting and conveying and delivering the material.

The central illustration on page 213 shows the bucket on its way with its load. The one at the right shows the bucket in the act of dumping its load. The importance of this from an engineering standpoint is, of course, great; it helps to solve one of the problems relating to placer mining.

About five years ago some experiments were tried near Topeka, Kansas, in which a clam shell bucket was ap-

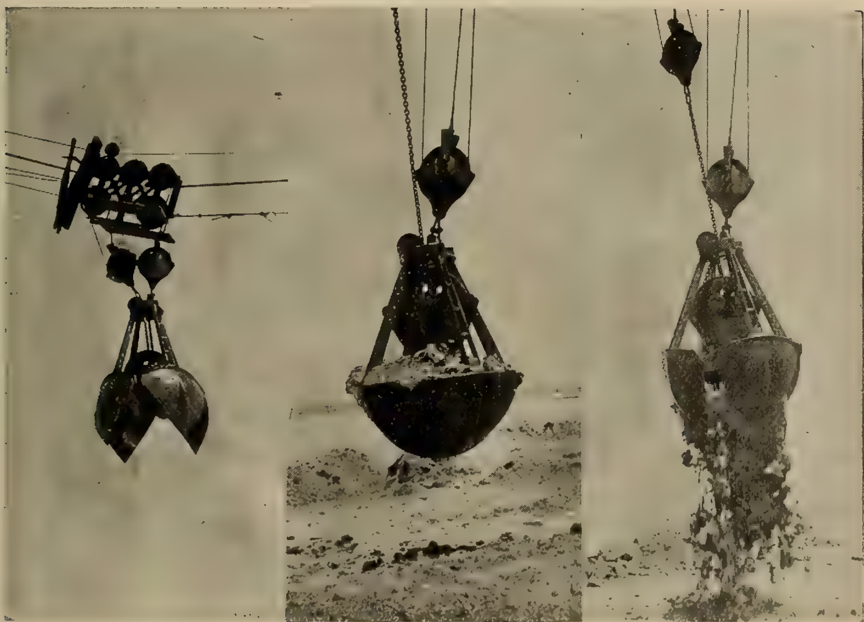


THE BUCKET DUMPING.

plied to a short cableway, and it was understood that it did the work quite successfully. The only machine of which there is any record, does not show one which is at all in a perfected state, but it is undoubtedly entitled to the credit of being the pioneer in the use of the self-filling bucket upon a cableway. This machine was used in handling deposits from river beds and streams, and delivering them to the sluice way on the bank. The invention was known as the Excelsior dredger and carrier.

These machines therefore become rivals to the steam shovel or dredge, and have many advantages not to be found in any steam shovel or dredge, among others the distance to which the load may be delivered after it has been excavated, and also the fact that the entire machine rests upon the banks, entirely clear from the intended excavation. This is a matter of considerable importance in some installations.

The cableway has been constructed on spans up to 1650 feet to hoist, conveying loads at a very high speed, and the load may be delivered in mid-air with the aerial dump, and at any point along the line of the cableway. The entire cableway, too, has been made portable, so that it travels on rails at right angles to the directions of the cable itself, and it is entirely practicable to use, depending from the load carriage, either a common flat skip, a self-filling grab bucket, or a scraper bucket, and with a choice of the three any sort of material can be excavated. In stripping a mine the first material to be removed may be loam, for which the scraper bucket is available; if sand or any soft material be found, the grab bucket may be used, and finally, for the work of excavating rock a flat skip may be employed and the material filled by hand, or if stone is found in large masses it may be chained directly to the fall block, and delivered to the spoil bank, or cars, as desired.



BUCKETS AT DIFFERENT STAGES.

To recapitulate briefly,—the cableway has been constructed with single spans up to 1650 feet,—it has handled 25-ton loads and it has delivered an average daily capacity (10 hours) of 617 place

yards of rock, equivalent to 1200 tons. It will hoist at any point and deliver at any point.

We may place limitations on the practicable application of the cableway as follows:—Span (single), 2000 feet; load, 25 tons; speed of travel, 1800 feet per minute; speed of hoist, 900 feet per minute. The average practice, however, is about as follows:—Span, 600 to 1200 feet; loads, 3 to 7 tons; speed travel, 500 to 1000 feet per minute; speed of hoist, 150 to 300 feet per minute.

After the work has been excavated by cableway, the rope tramway, as shown on page 210, serves admirably for conveying over rough country to a railroad or boat, and when delivered by boat to its destination, a cableway like that shown on page 204, is valuable for discharging the ore.

THE BLIGHT OF TRADE UNIONISM.

A Review of British Labour Conditions.

By Benjamin Taylor, F. R. G. S.

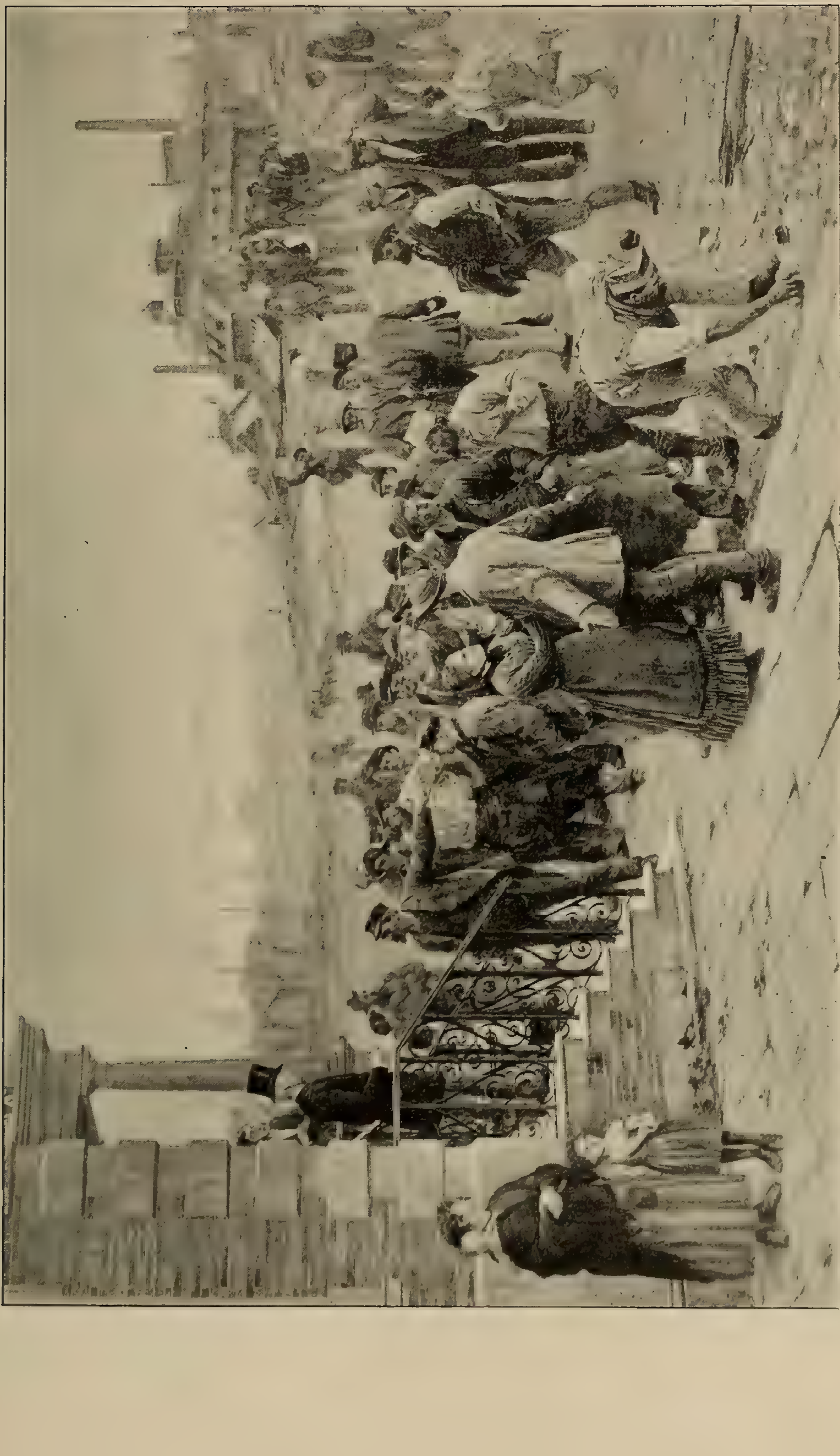
THE praises of trade unionism have been so persistently and so loudly sung by political reformers and social economists—if persons so sedate can do anything so frivilous—that he challenges the doom of a heretic who ventures to suggest doubt of the value of this feature of the industrial system. What, then, shall befall him who ventures to deny the virtue of trade unionism and to denounce it as a social and industrial blight?

Let us clear our minds of cant on the subject and approach a consideration of it without either passion or prejudice! Let us not begin by assuming, on the one hand, that because trade unionism is, it must, therefore, be right; nor on the other, that because it ought not to be at all, therefore it is wrong. To the theory of trade unionism we have no objection to offer. The right of men to combine for advancement of their own interests, the protection of their own rights, the improvement of their own lives, and the provision for their own comfort, is the undoubted right of citizenship. Whether it is always wise to exercise a right that is indisputable is another matter.

But we are not concerned just now with ethics or with philosophic theory. The question we have to consider is whether trade unionism as a legitimate evolution of citizenship has been good for the citizen and the State, or good for the citizen and bad for the State, or bad for both citizen and State; whether, in short, trade unionism has been a blessing or a blight on our industrial system.

The very stating of the question may cause a moral shock to those who have been brought up to regard trade unionism as a creature as sacred as the British Constitution,—as the palladium of the rights and liberties of the British workingman. It may even serve to suggest uneasy feelings to those politicians and political agents who have sold their birthright of independence for a mess of trade union pottage in the form of votes. For trade unionists are possessed of the belief that it is trade unionism and trade unionism alone that has advanced the wages of the workers and improved the conditions of work, and this belief they have succeeded in impressing on others.

Trade unionism, however, is only an incident in the general development of society. It could not have raised wages and improved the condition of the workers if the economic conditions did not admit of such changes; and conversely one may argue that these changes would



REPRODUCED BY PERMISSION FROM THE ORIGINAL PAINTING, BY ROBERT KOEHLER.

THE STRIKE.

have been brought about in the natural order of things. The tendency of all grades of society is upwards without any organisation or combination of classes further than is comprehended in the general term Democracy.

In the study of trade unionism one is compelled to observe often what is not the same thing,—mobocracy. There is nothing more tyrannical than the tyranny of a mob, and this is just the kind of tyranny that our leading industries have been, from time to time, subjected to,—from coal-mining to cotton-spinning, and from shoemaking to engineering. What we find in these trade organisations, — and the more pronounced, the larger and stronger the organisation,—is that the members become slaves of their own societies, the tools of their own servants,—paid officials.

Why do trade union officials frown upon profit sharing and look askance at co-operation? Because they regard with jealousy and hatred anything which may tend to weaken the loyalty or slacken the devotion of men to their unions. Why do they discourage piece-work and endeavour to fix a minimum and a maximum standard of work? In order that, by the distribution of work over a larger number of men, the unions may be enlarged in membership and in power.

It is quite true that trade unionism is in essence a vehement expression of individualism, and, as such, is the antithesis of socialism. But it is very true that when a worker joins a trade union he loses his individuality and becomes merged in a system which, paradoxical though it seems, while the converse of socialism, is a form of socialism. A trade union lives and moves and has its being not for the good of each individual member, but for the glory and power of the society. It may not profess to seek, but it does succeed in creating a dead level of mediocrity. The object is not to obtain the highest pay for the highest merit, but the highest pay for the lowest merit. In this respect trade unionism has succeeded in raising wages,—in exacting for the inefficient worker more than he is worth. By so doing it has injured the efficient worker and burdened industry with dear, inefficient labour.

In what respect can such a result be beneficial? The two most serious blows ever dealt against human institutions were dealt when trade unionism began to eradicate the spirit of emulation in the workshop, and to loosen the bond of sympathy and good will between employers and employed. When the union steps in between man and man there is no honorable rivalry, but a reduction of industry and skill to the level of the least efficient; and when the union comes in between master and man there is distrust and disorder.

The insidious poison of the doctrine of the new unionism is eating into our social organism; it is, that a man shall not do his best, but his least for the wages he receives. Is the labourer worthy of his hire when he owes allegiance first to his society, and only second, to his master?

Our point, then, is this, that, however right trade unionism may be in theory, it is wrong, wofully wrong, in practice. One does not need a better object lesson in human unreason than is afforded by the periodical reports of proceedings of the trade union congresses. It is, indeed, somewhat surprising that trade unionism should survive these displays of fatuous ambition and extravagant pretension. But at these gatherings we see merely what characterises the management of most of the unions,—ignorance of the most essential conditions of national welfare, industry and justice. Reduced to plain terms, their creed is that it is the right and duty of every workingman to get as much money as he can out of his employer and to do as little for it as possible. The name of "workingman" for an artisan is becoming a misnomer,—will, indeed, so become if Mr. Tom Mann and others who aim at a nine-hour day can have their will.

And why trade unionism is hurtful and has been prejudicial to our national industries is not difficult to see. It has

established the rule that the incompetent man shall be paid as high a rate of wage as the competent,—which is unfair, unjust, discouraging and in every way harmful to the superior workman. By discouraging piece work it strives still further to reduce all workmen to the common denominator of the "duffer." Instead of inducing incompetent workmen to improve themselves, it compels competent workmen to work slowly and badly. Many unions, it must be remembered, take in, for the sake of the contributions, all who claim to belong to the trade, however ignorant and incompetent. And the general effect of all this is necessarily to make the cost of production needlessly large, to the prejudice of all consumers, including, of course, workmen themselves.

Let us now take a survey of some of the practices of trade unions as regards their own members, other workers, and the employers of labour, and in the general conduct of industries to illustrate for what they are contending. Some of the most instructive instances are in connection with the jealousies among trade unionists themselves.

In September, 1896, a demarcation dispute between caulkers and drillers occurred at the shipbuilding yard of Messrs. Armstrong, Whitworth & Co., Limited. The caulkers claimed the cutting-off of the squares of tap-bolts, which are used in water-tight work and work in confined spaces to secure plates by screwing and not by riveting. After the tap-bolt is screwed home, the square requires cutting off. The drillers claimed that they had always done the work in the yard, and it did appear certain that they had done the most of it. The matter was ultimately referred to three referees, but the caulkers refused to accept their decision and went on strike, rather than work under the award. They were, however, induced to return to work and to give three months' notice to terminate the award, and eventually both parties agreed, before the notice expired, to allow the employers to settle the matter.

Demarcation disputes between the Joiners' Unions and the Shipwrights' Society are of constant occurrence, especially on the North East Coast. The Joiners' Society in that district seeks to include or keep under its sway the smaller wood-workers' societies, such as Cabinet-makers, Mill Sawyers, and Machinists. Some time ago, because the cabinetmakers desired to be independent and work on their own bottom, the joiners refused to work with them, and tried to strike them out of the yards.

There was recently a demarcation dispute between shipwrights, caulkers and smiths at the Walker yard of Sir W. G. Armstrong, Whitworth & Co., Limited. After a strike of shipwrights, because the firm would not hand over the work to them without reference to the caulkers or smiths, the Employers' Association got the parties to agree to allow three employers to give a decision, —that is to say, the associated employers had to interfere to make peace between the infuriated trade unions!

A remarkable case was that, in 1890, of the joiners' strike against Mr. Burt's award on a demarcation of work dispute between joiners and shipwrights. Mr. Thomas Burt, M. P., was mutually chosen as umpire of a court of arbitration. He issued his award in March, 1890, and the joiners refused to abide by it. The employers upheld the award and the joiners struck work till November 3, 1890, when a conciliation board was formed, consisting of representatives of the different sections of workmen, and presided over by the Mayor of Newcastle, who ordered the joiners to resume work on Mr. Burt's award on November 3, and offered to revise, at the request of both parties, thirty-two items of that award. This was done, each side submitting sixteen items. The demarcation disputes, however, between these two trades still go on. Some are settled by a standing committee consisting of three employers, three joiners and three shipwrights, and some are not so settled.

As a glaring instance of the latter may be noted the case of a firm on the Tyne who bought a new boring machine at the beginning of the year, and be-

cause both joiners and shipwrights claimed to work it, and because neither would allow it to be worked till it was settled which of them should work it, the machine has been idle nearly a year. A short time ago this firm wished to complete some tumbler-racks and set a lad to do them in this machine. The shipwrights immediately went on strike, stating they would not allow any one to work the machine till it was settled whether joiners or shipwrights had to work it! The joiners claimed this machine for the machinists,—a section of men allied with them in trade union matters.

In April, 1891, there occurred at Jarrow what is known as the Fitters' and Plumbers' demarcation strike. On April 27 the engineers struck at Palmer's shipbuilding yard, and refused all attempts at conciliation until on June 13 the employers on the Tyne and Wear gave notice that 25 per cent. of Amalgamated Society of Engineers men would be locked out if the Jarrow dispute was not settled,—a dispute, it will be observed, between two trade unions.

On June 19, 1891, the men resumed work, it being agreed that a conference of three employers, three fitters, and three plumbers should sit to settle the points in dispute. The engineers during the conference disagreed with one decision arrived at by the majority, and left the conference, refusing to attend any more meetings. The conference went on and finished its work of demarcation.

The employers determined to enforce the award in January, 1892, and the men at Palmer's went out. Thereupon the Tyne and Wear employers locked out the members of the A. S. E. in their employment on January 30, 1892, and not until April was a settlement effected.

In October, 1891, a strike of engineers occurred on the overtime question, the object of which was the restriction of overtime. This was a "one-man" strike promoted by Mr. Glennie, then secretary of the local A. S. E. committee in Newcastle, and now an assistant secretary at the head offices of the society. Mr. Glennie, having failed to get up a good row on this subject (the employers being willing to restrict overtime within certain well defined limits), led the engineers into the Fitters' and Plumbers' strike, just referred to. Mr. Glennie was in 1892 a candidate for the general secretaryship of the A. S. E.

As a matter of fact, the engineers like overtime and always evade the society's restrictions when they can. It is said that large numbers of the engineers in Newcastle have bought (through building societies) and furnished their houses out of overtime pay.

A curious case occurred at Hartlepool in 1889, when a foreman in one of the shipyards happened to speak disparagingly of the banner of the National Labour Federation which was being displayed at a parade of the league. For this heinous offence the foreman was "reported" to the headquarters of the league, and the firm were summarily called upon to dismiss the offending foreman. Naturally they refused to do so, and then the whole of the members of the federation in the yard struck work. The strike lasted for several days, and might have gone on for months, but the disgusted foreman resigned rather than have his employers put to further inconvenience.

The disputes between joiners and carpenters, to which reference has been made, had a further complication at Barrow. There the joiners in the employment of the Naval Construction and Armaments Company used to make the patterns for the heavy castings required for the hulls of large steamers and warships. The Patternmakers' Union claimed this as the work of their members, and as the joiners refused to give it up, the dispute between the two unions resulted in a strike in 1889.

An interesting case occurred at the Thames Iron Works, a concern supposed to be in especial favour with trade unionists generally, and the A. S. E. in particular. A few years ago the members of the Boilermakers' and Iron Shipbuilders' Society employed there struck work because of the employment

of non-society men. They held out for some time, but as the employers would not give in the unionists had to go back, sadder and poorer men.

A little later, in the same works, several hundreds of A. S. E. men went out on strike on some technical and trivial question of allowances laid down by the society. After keeping the works idle for some time they gave in.

As an illustration of trade union methods of putting on the screws, take the following:—About the beginning of 1897 the A. S. E. on the North East Coast gave notice demanding an advance of wages, and, according to their established custom, this notice had a month to run. But within ten days after the notice had been handed in to the employers, the A. S. E. men at Hartlepool suddenly stopped overtime working, without any intimation of their intention of doing so. When remonstrated with, they frankly said that this was their method of pinching the employers to make them hurry up a decision on the wages question.

The strikes against the employment of rival union, or non-union, labour have been legion and are incessant. There have been many rebellions at Hull, Barrow, and other places against the employment of members of the Machine Workers' Association at machines which members of the A. S. E. demanded for themselves. But the Machine Workers can play at the same game when they have the chance, and we know of an engine shop in Scotland, where they happened to be numerically strong, where they threatened to strike unless an A. S. E. man was summarily displaced from a machine to which he had been put.

The Federated Engineers' Employers have, of course, large numbers of men employed as machine workers whom they have trained and raised from the ranks of unskilled men. It is a curious fact that in several instances these men have protested to their employers against the promotion of other men in the same way as they themselves have been advanced. In other cases, when it has been necessary to move men from one machine to another, members of the Machine Workers' Association have refused to go to machines that had been previously worked by members of the A. S. E., though, as far as we know, an A. S. E. man has never refused to take a machine previously worked by a Machine-worker.

A notorious case of striking against non-union labour was that at Messrs. Dunsmuir & Jackson's Works at Govan, Glasgow, in 1896. There, some fifty members of the A. S. E. demanded the dismissal of a non-union employee, and went out on strike until the demand was complied with. Of course, the firm refused. On their part the men refused to obey the order of their executive to return to work and leave the matter to their officials to settle. They remained out for many weeks, during which they kept the works idle, and went back only when they had reason to believe that the man objected to had got a situation elsewhere, to which he meant to move as soon as his employers would allow him. This they would not do while the men were on strike, nor would they listen to any condition in the matter.

Nevertheless, the inference seems to be that the A. S. E. men would not have terminated the strike had they not known that the non-union man was going away. This was a case of interference with non-union labour, which the leaders of the society say had not their sanction. Nevertheless it was the action of members of the society, supported by the local branch.

Some curious troubles have at times occurred in connection with labourers in the shipyards. In dull times a skilled artisan belonging to one or other of the superior unions, or perhaps to no union at all, will gladly take a job as labourer until something better is available. But the Labourers' Union have adopted the tactics of the "skilled" unions and have attempted to prevent the employers from taking on skilled operatives as labourers! It is interesting to compare this action with that of the A. S. E., in attempting to prevent the employment of labourer as machine-minders.

One of the most remarkable of all the

demarcation disputes was that between the Boilermakers' and the Engineers' Unions as to which trade belong properly certain portions of the work of making Belleville water-tube boilers. The one union claimed that each tube is, *de facto*, a boiler, and that therefore the fitting belongs to the boilermakers. The other union claimed that the water-tube boiler is not a boiler until all the tubes are fitted together, and that therefore the work of fitting is the work of an engineer fitter. Long and furious was the contest waged over this question, which, undoubtedly, was as interesting as it was novel.

The Belleville boiler was not only a remarkable invention, but it raised the conundrum, "When is a boiler not a boiler?" It brought two of the largest and most powerful trade unions in the world into such heated contact as to threaten a trade union war of disastrous magnitude. For months the dispute went on, until the two societies came into conference, at which they were unable to agree on either the definition or division of the work.

At last it was agreed to submit to the arbitration of Mr. David J. Dunlop, the eminent shipbuilder of Port Glasgow, who called the parties before him and heard the evidence and arguments on both sides in a most judicial, as well as judicious, manner. What he had to decide was on the claim of the Boilermakers' Society to "the right to connect all tubes and expand them when necessary; also to test all tubes and erect all the elements, and put in all the doors, large or small," in the construction of water-tube boilers. This claim was founded upon the industrial right of boilermakers to make boilers; but was resisted by the Engineers' Society, on the ground that so great have been the transitions in the Belleville boiler that it has lost all the characteristics of a boiler and can be regarded only as an elaborate piece of mechanism, the putting together of the "elements" of which is the work of an engineer. For the preparation of the tubes and the various items forming the "elements" the boilermakers made no claim. The dispute really turned on the fitting together of the "elements" to form the complete boiler, and this is work which is quite capable of being done by either class of workmen. Mr. Dunlop, however, decided that the particular portion of work which formed the subject of reference is boilermakers' work. This decision by no means pleased the A. S. E., and, though they have abided by it, the breach between them and the Boilermakers' Society has never been healed.

In this connection it is worth recalling what was said by Mr. Knight, the general secretary of the Boilermakers' Society, in opening his case before the arbiter:—

"Up to the present time we have kept ourselves free from disputes with other societies respecting the demarcation of work, as we have kept to the branches of our own trade and have not attempted to encroach on the right of others. * * * The calamitous strikes that have taken place in our different districts respecting the demarcation of work between the ship-carpenters and the joiners, also the engineers and plumbers, of the effects of which we are suffering to this day, ought to be a lesson to every one to discourage any attempt at interference on the part of any society to take what belongs to another. If this is not done, and societies follow the example of the engineers in the present case, peace in the industrial world will be impossible, and chaos will reign supreme."

It was, doubtless, this long-standing feud between these two great unions which caused the Boilermakers' Society, happily, to withdraw from the London Joint Committee of Trade Unions when the demand for an eight-hour day was made in July last. That there is still no love lost between them is constantly shown by documents issued by one or the other. In the last monthly report of the Boilermakers' Society, for instance, we read:—

"Our members are suffering severely through the engineers' strike and will certainly have to for some months to come. Surely if any one has cause to

complain it is we, and we cannot quite understand how it is that we have been receiving so much attention at the various meetings recently held by the engineers, of a not very complimentary character. * * * Unfortunately for them there has been a great deal too much said. Arrogant talk and loud declamation is the bane of any cause, and the engineers have suffered more from this than they are aware of. * * * We think any fair-minded man will admit that if there is cause for complaint it is on our side. In the adjustment of difficulties and in dealing with questions affecting the interests of our members, we prefer doing it in our own way."

Of course, the A. S. E. hit back, and so the controversy goes on. Meanwhile, Mr. Knight's society, whose "way" has been to swallow all the lean kine until it practically includes all the craftsmen in the trade, has had its own domestic troubles. The London branch revolted because it was not allowed by the executive council to strike for an eight-hour day before the society, as a whole, was ready to make the demand. And the society is not ready because the officials well know that the employers will not grant it, and that a general strike must result in the bankruptcy of the Boilermakers' Society.

It so happens that the very strength of this trade union is its weakness. Practically all its members are in the employment of the Federated Shipbuilders and Engineers. In the shipyards the boilermakers and riveters have, by their organisation, succeeded in enforcing a scale of pay far beyond the value of the manual labour and small technical skill involved. Compared with other crafts, riveters' wages are almost grotesquely extravagant, and there is not the slightest doubt that the organisation of the Boilermakers' and Iron Shipbuilders' Society has enormously increased the wage cost of construction of ships in British yards, and has largely assisted in the diversion of orders for ships to Germany and elsewhere.

It is the very closeness of the organisation, however, that makes the Boilermakers' Society cautious about coming into conflict with the employers. To make any demand which the employers, as a body, must resist, would result in the locking out of all the shipbuilding yards in the kingdom. This would mean the total stoppage of the income of the Boilermakers' Society, which, in this respect, occupies a less advantageous position than the Engineers' Society.

In other words, the Boilermakers' Society has become so strong as a trade combination that it is crippled as a militant body. Its accumulated funds would enable it to maintain a strike for a certain limited number of weeks and no longer. Then it must capitulate on such terms as the employers would be disposed to concede. This is a very interesting phase of trade unionism and presents an object lesson to all employers in the value of combination for the protection of their own interests against organised labour.

One of the points made by the Engineers' Society in the water-tube boiler case was that the boilermakers at this work had to use engineers' tools. About two or three years ago another tool difficulty occurred at the Naval Construction and Armaments Company's yard at Barrow. There the engineers one day struck in a body and threw the works idle because the caulkers working at some ship had "engineers' tools" for a portion of their work. It is not a joke, but a fact, that the tool of offence was a simple file!

In short, a very large number of the most bitter disputes in our industries have been among the trade unions themselves. Of late years there have been more quarrels, more bad blood, and more stoppages of work in the engineering and shipbuilding trades in connection with demarcation than in any questions between employers and employed. It is these disputes which threaten the destruction of trade unionism. But they do more than threaten trade unionism. They threaten the whole existence of our industry, disturbing alike the calculations and operations

of the employers, increasing costs and annoying customers by vexatious delays.

There are sometimes unions within unions. Such an *imperium in imperio* may be found in more than one of our great fleets of ocean liners. In some of these fleets the Engineers' Union have obtained the practical mastery of the steamers, holding the captains and officers in the hollow of their hands. The captains dare not quarrel with them or something would happen to ruin the voyage and the commander's reputation. And if the engineers on one boat take a dislike to any officer they will compel his discharge by simply refusing to start the engines, and will pass his name through the fleet to prevent his engagement on any other vessel in the service.

Another interesting example of trade union practices has been given by Mr. Jeans from his own observation. A trading vessel, in making for Newport, had an accident to its machinery. The only workmen available to execute the temporary repairs needed did not belong to the class permitted by the society to do such work, but they "turned to" sufficiently to enable the vessel to get into harbour. Then steps had to be taken to have the repairs more completely and efficiently carried out and men were obtained for that purpose.

This brought the union officials on the scene, scandalised at hearing that "outside the port unconsecrated hands of workmen, not specially accredited, had touched the work in the absence of those who had been duly chosen as alone qualified." Thereupon the men were called off the job and the owners of the ship were informed that unless they both apologised and made compensation the ship should not be repaired! The owners had acted in innocent ignorance of trade union etiquette, and were in a hurry. They salaamed to the trade union officials, made the *amende honorable*, and then were graciously allowed to complete the repairs.

With regard to piece work, it has been pointed out by Mr. Jeans that the eight-hour day might be granted to-morrow if the men would go on piece wages instead of day wages. The essential condition of labour organisations is that every member shall work under the conditions laid down by his union, and under these alone. That means that he must do only certain kinds of work and a certain amount of work. A limitation is placed upon his industry in the supposed interests of the other members of the trade. If he has to work machine tools, he must work only one at a time, though his competitor in Germany may be working three and his compatriot in America may be working six tools of the same kind. This is done on the same principle that piece work is discouraged in the design to provide work for as many men (actual or potential members of the union) as possible.

It is a delusion, as is also the theory that the man who works overtime is taking so much from the common stock of labour to the injury of other labourers,—as if it were always possible for one man to begin where and when another leaves off. But it is just in pursuit of such delusions that the trade unions are most harmful,—in repressing individual energy, fostering degrading espionage, and adding on every hand to the anxieties and costs of industrial production.

In the light of all one's knowledge and of the plain facts pressing with cruel severity upon one of the greatest of our industries, it is amazing to read what one trade union writer says:—

"The effects of trade unionism in the engineering trade may be briefly summed up as follows:—First, it has immensely improved the morals of the workers. By bringing them closer together and placing them under a system of discipline they are brought to feel that they are not single units, each fighting for his own hand, but that, within certain limits, each is responsible to his fellow workers. It inculcates thrift, mutual reliance upon each other's sympathy and assistance in need, while at the same time, it breeds a spirit of firm independence and of strong an

united opposition to all forms of industrial oppression among its members. It has raised wages and reduced the hours of toil and lessened, to some extent, many of the other evils of workshop life, such as piece work, systematic overtime, and the favouritism or bullying of foremen.''

Thus wrote Mr. Swift, formerly of the A. S. E., though now, we believe, of the rival Steam Engine Makers' Society, in a chapter contributed to a volume about '' Workers in their Industries,'' published a year or two ago by Messrs. Sonnenschein.

And Mr. Swift went on:—''That the unions have not been more successful in their objects than is actually the case is due, to some extent, to their conservative tendencies and their slowness to change and to take advantage to the full of all their opportunities. But still more is it due to the selfishness and desertion of their fellows of the non-unionists, who are content to take all the benefits which the union has obtained, while unwilling to do their share in paying for these privileges.''

There speaks, of course, the trade union official. But '' improved morals '' when men are deliberately defrauding their employers of a just measure of labour paid for? '' Thrift '' in throwing away hundreds of thousands of pounds in warfare with other unions and with employers? '' Firm independence '' when each member sneaks under the eye of his shop steward and cowers before his branch committee? '' Opposition to individual oppression '' when its whole machinery is employed to coerce or crush the members of other unions and to prevent non-unionists from obtaining an honest living?

The one thing that first caught public attention in the machine question was the evidence it afforded of the tyranny of one large trade union over the workmen in a smaller union and over workmen in no union. And the most startling product of the recent prolonged strike has been the damning evidence which it has called forth of the dishonest working of trade unionists, proved by the enormous difference in the output from the same tools by non-unionists issued to them since the strike. Before the long indictment of '' Restrictions and Interferences,'' published by the engineer employers, trade unionism stands exposed as the bane, not the blessing, of labour.

If our illustrations of trade union practices have been chiefly drawn from the engineering and shipbuilding trades it is because these trades interest the greater number of the readers of this magazine, and also because these trades have been so prominently before the public of late. But, indeed, abundance of illustrations can be drawn from every branch of industry in which trade unionism has acquired any hold. How its blighting influence may extend even to destruction, the lace-makers of Nottingham well know. How it may drive a trade out of the country the flint glass-makers can tell. No industry, perhaps, has been more completely manacled by trade unionism than glass-making, in which not even an employer's son can be apprenticed without the consent of the union, and in which an employer cannot get rid of a drunkard and incompetent workman without the approval of the branch committee.

What has been the consequence? British flint glass is now so dear that only the wealthy can afford it; everybody else buys German glassware. And so, in the same way, our Bottlemakers' Unions have given away our immense trade in glass bottles to Belgian, German and Swedish makers.

But though instances of the crippling and destructive effects of trade unionism are endless the space available here is limited. We have cited enough in support of our contention that the effect of trade unionism on industries is positively hurtful. It has not only driven several once prosperous trades out of the country, but it has also driven away some of our best craftsmen, who, failing to find an outlet for their craftsmanship here, have had to emigrate. Need it be said that a system which is injurious to the industries of a country cannot be otherwise than hurtful to the industrial workers of the country?

The trade unions think that they have raised wages,—and so they have, sometimes, as in the case of the boiler-makers, to a point far beyond any reasonable valuation of mere manual labour, and sometimes, as in the case of the glass-makers and the Nottingham lace-workers, so far as to make the conduct of the industry impossible. But on the whole, they have not raised wages more than they would have risen in the natural operation of the law of supply and demand. On the contrary, it is probable that wages in most industries would now be higher than they are had not trade unionism placed such an advantage in the hands of our foreign competitors. In proportion as we have allowed foreigners to take industrial production away from us, so have we narrowed our natural avenues of employment. But as, at the same time, we have not reduced the number of those desiring employment, there are larger numbers in every trade than there is need for.

We are not disputing here the right of workmen to combine for the advancement and protection of their craft. Nor is it to be denied that such right carries with it the right for each trade union to make such rules and regulations as it deems fit for its own members. Where the mischief begins is when trade unions seek to make rules which fetter other workmen and which tie the hands of employers. And where trade unionism begins to be absolutely destructive in its effects on industry is where, on the one hand, it endeavours to make a close corporation by limiting the number and restricting the employment of apprentices; and where, on the other hand, it restricts the labour of the most competent to the capacity of the most idle and least efficient.

All this trade unionism does. Overtime is objected to because, it is alleged, it diminishes the number that may be employed. But if overtime is not worked orders cannot be executed within the time in which they are required. Therefore the orders will cease to come, and because Bill was not allowed to work extra hours, Jack, Tom and Jim will not be able to get work at all.

While earnest efforts are being made throughout the country to extend technical education, trade unionism has been using all its efforts to throw away the benefits that might have resulted.

While a howl has been raised throughout the length and breadth of the land against alien immigration, trade unionism has opened our doors wider and wider to the products of alien labour. In an age whose note is freedom, trade unions return to an ideal as old as feudalism and as tyrannical as the old Guild System, which was the ruin of the mediæval free cities.

The stories of "demarcation" quarrels reveal to us a system of caste that would be, if allowed, as rigid and jealous,—and also as morally destructive,—as that of India.

As to the raising of wages, there is, no doubt, a prevalent belief, not in trade union ranks alone, that this has been effected by trade unions. Now if it has, without economic reason, then trade unionism must have been a gigantic evil to the consuming millions. By how much the cost of living is artificially enhanced, by so much are all classes, and especially the poor, injured. If, then, trade unionism has achieved what it claims to have done, it stands condemned out of its own mouth.

But our point is that not to trade union effort, but to natural industrial and social development, is due the improved condition of the working classes; and that the condition would have been still better than it is if the restrictive action of trade unionism had not, in various ways, enhanced the cost of production; that cost would have been lower, while wages would have been better than they are, had there been no such restrictive action; and that by driving industries abroad the trade unions have both over charged their own ranks and overburdened the country with a mass of unemployable labour.

It is, no doubt, difficult for the politician who has accepted trade unionism as a political force, and for the emotional philosopher who has persuaded

himself that it is an economic paragon, now to believe that it has failed on every one of the points on which its existence was justified by the old economists. But we must take it as we find it, and as we find it trade unionism is an industrial blight. It will be urged, and must be admitted, that all trade unions are not so aggressive and obstructive as some. But we can only regard the system as a whole, and, as has been remarked, "it's ill telling who is Old Harry when everybody's got boots on."

DUSTLESS BUILDINGS.

By C. J. H. Woodbury.

A Paper Read Before the American Society of Mechanical Engineers.

THE increased height of office buildings, rendered possible by what Otis Tufts patented as the vertical railway, while bringing to their occupants relief from the noise of the streets, and affording comfort by extending above the fly belt, which is as well defined as the snow line on a high mountain, also exposes the occupants to the fine dust which pervades the whole structure and which the other salutary conditions of the building renders more prominent.

The modern method of heating and ventilating such a building is by means of a blast of air drawn down a flue, warmed and forced through the building in such quantities that four times the volume of the building is frequently circulated through the rooms each hour.

This method of heating represents a more efficient application of radiating surface for heating the air than by direct radiation in rooms, and can be managed with far less expense for attendance, repairs and fuel, and provides the sanitary requisite of ventilation without cold drafts; yet this apparatus distributes large amounts of dust through such a building, and in a city using bituminous coal under the average conditions there is a fine carbon dust which is especially obnoxious, impairing drawings, books, delicate mechanism, and whatever may be injured by such dust, which produces black indelible smooches whenever touched. This carbon dust is always an annoyance and at times a serious matter.

The writer undertook to abate the difficulty of dust in a building of nearly 500,000 cubic feet capacity, through which 26,000 cubic feet per minute were usually blown for heating and ventilation. The outside air used for this purpose was drawn down a flue 37 square feet in cross section, and reached a velocity of 700 feet per minute.

The means taken to remove the foreign substances from the air were the use of cotton cloth filters so arranged that the air should approach the fabric at an acute angle by which the momentum would carry these particles beyond a point where the element of air under consideration would pass through the filter, and the particles of dust would be carried by the place, and striking the cloth at a lesser angle, tend to glance off and be carried to the bottom of the filter, rather than to clog the interstices in the fabric. The area of the filters being larger than that of the flue, the rate of filtration was inversely slower than the velocity of the air down the flue.

The means by which this was accomplished were very simple. A timber frame, divided by partitions into fine rectangular openings, was placed at the top of the flue, and under each opening was placed a bag whose top was attached to a light wood frame slightly larger than the opening, making a tight fit, so that the air entering the flue must pass downwards into these

bags which were over thirty feet in height. An arrangement of guides, ropes, and pullies enabled the bags to be raised and lowered by a person at the bottom of flue. The bottoms of the bags were made open, and closed with a drawing string, and hoops kept the lower portion distended. An arrangement of lines extending along the sides from end to end facilitated turning inside out and back again when they were being cleaned. The whole of the mechanical arrangement is fully described in U. S. patent No. 589, 772.

These bags were square at the top where their combined area equalled that of the flue, but soon diminished to a cylindrical section, occupying about 40 per cent. of the space, thus affording ample clearance for the exit of the air passing through the fabric.

The area of the flue was 3¾ per cent. of that of the bags, and while the air passed down the flue at a velocity of 700 feet per minute, it passed through the fabric at 26 feet per minute. From half a peck to a peck per month of fine dust was gathered from the bags.

The efficiency of the device was tested by placing freshly-painted boards at the bottom of the flue before the installation of the apparatus, and then giving another coat of paint after the apparatus was in service. In the first instance the fresh paint collected fine dust until it resembled fine sand-paper, and in the second the paint dried with a smooth surface.

In several of the offices split laps of absorbent cotton were placed in various parts of the building before and after the bags were in service, and one set was covered with fine particles and the other was free. The change was not a notable one at first, owing to the large amount of dust in the flues, but much of this was removed by running the blower at a very high rate of speed, and afterwards removing the registers and washing them and the flues as far as could be reached.

The device has been solely under the care and management of the men employed on the engine and boilers, and has served its purpose in rendering a building free from dust caused by the ventilating system.

A MIDLAND EXPRESS TRAIN, WITH DINING CARRIAGES.

CARRIAGE AND WAGGON BUILDING ON THE MIDLAND RAILWAY, ENGLAND.

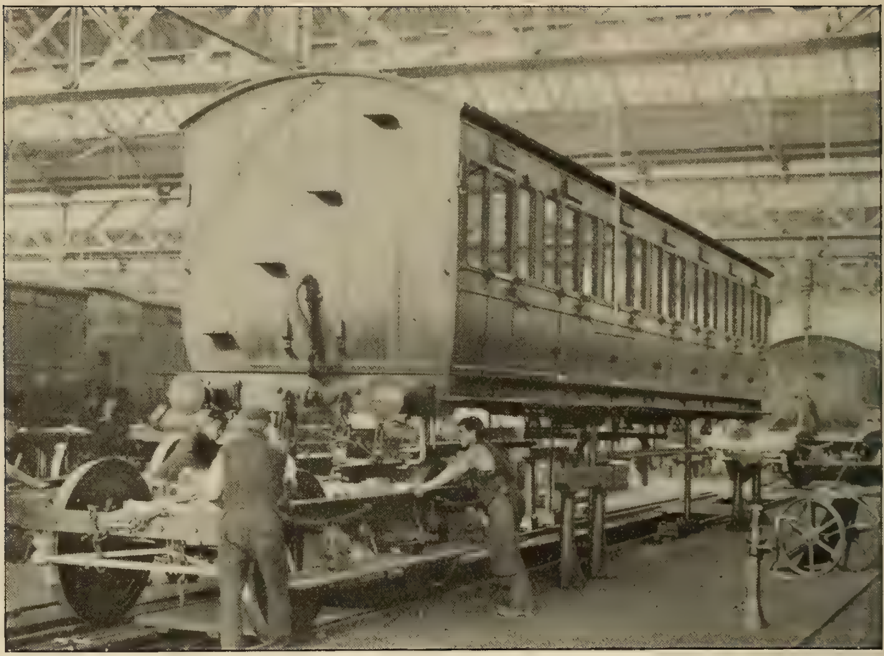
By Charles Henry Jones, Assistant Locomotive Superintendent of the Midland Railway, Southern Division.

IN the year 1895 there were in the United Kingdom alone 21,174 miles of railway open for traffic. The trains ran 338,000,000 miles, and carried 929,000,000 passengers and 334,000,000 tons of goods and minerals; 18,658 locomotives and 677,028 vehicles of various kinds were engaged in dealing with this immense traffic.

With these figures before us, it is difficult to realise that there are many people still living who remember the time when there were no railways. They can recall the long, wearisome journeys by stage coach, exposed outside to the inclemency of the weather, or so closely packed inside that they could not indulge in any change of posture to relieve their cramped limbs. The risk attending such journeys was thought to be so great that people arranged their affairs and made their wills before taking them.

In those days, all merchandise was conveyed from place to place in carts, on pack horses, or in easy-going canal boats, whereas now trains of forty or fifty waggons, carrying hundreds of tons of goods and minerals, follow one another in rapid succession throughout the day and night along all the great lines of railway, and the traffic reaches its destination in as few hours as formerly it took days. Trains conveying hundreds of people rush through the country at fifty or sixty miles an hour, and passengers are accommodated with luxuriously fitted carriages lighted with gas or electricity, and warmed by artificial heat. They are able to dine and sleep en route, and every care is taken to guard them against accidents.

The first important railway used for passenger traffic was the Liverpool and Manchester, opened in 1830. If we compare the vehicles forming the first train on that line with those of the present day, we must be impressed with the fact that the improvement in their character has been no less extraordinary than the development in the traffic already alluded to. To be able to fully appreciate how this



LIFTING A CARRIAGE BY HYDRAULIC RAMS FOR CHANGING WHEELS.

change has been brought about so rapidly, one has only to look round the workshops of great railways, and see what wonderful facilities are now available for the construction of railway rolling stock.

In Derby, the centre of the Midland railway system, there are two establishments where the locomotives, carriages and waggons of the company are built and repaired. The town owes much of its prosperity to these great hives of industry, for they together support 8000 men, who, with their families, form about one-third of the 96,000 population.

The carriage and waggon works, planned by Mr. T. G. Clayton, superintendent of the department, cover eighty-six acres and are the most extensive works of the kind in Great Britain. They comprise thirteen large workshops of red brick, all much of the same design and of uniform height, besides offices, stores, messrooms, and commodious wooden sheds for seasoning timber. As the buildings contain so much inflammable material, they are separated from one another by spaces seventy feet in width, and other extreme precautions are taken to guard against the contingency of fire. The shops are conveniently arranged for the direct transmission of work from one to another without unnecessary labour. By connecting lines, and steam traversing tables, carriages and waggons can be quickly moved from shop to shop.

The buildings on the west side are devoted to wood working, and the erection and painting of vehicles. Timber of every description enters the works on railway trucks and is unloaded by powerful steam cranes. After being measured and carefully checked over, it is sawn into planks, panels, or scantlings. These are stacked in the yard, or stowed away in the drying sheds where they remain sheltered from the sun, but freely exposed to the air, for about two years, until thoroughly seasoned.

The east side of the works is devoted to metal working. Raw materials, iron, steel, and brass, first enter the foundry or smithy, where they are converted into

castings or forgings. These are passed on to the machine and fitting shops, and manufactured into wheels, springs, axle boxes, couplings, brake fittings, nuts, bolts, and hundreds of other articles which help to make up a railway vehicle. The wood and iron work are brought together in the erecting shop and built up into complete carriages and waggons.

The saw-mill has a cellar and all the main shafting, pulleys and belting, are down below. This arrangement reduces the liability of accidents, as it keeps most of the quick-running and dangerous machinery entirely away from the workmen. It leaves the floor of the mill clear for carrying or stacking timber, and the cellar also provides a convenient receptacle for sawdust and shavings from which they can be removed without interfering with the work going on above. The mill contains all the most recent and improved examples of machinery for working timber.

Here is a circular saw, 6 feet in diameter, revolving at a high speed. A huge oak log, 2 feet 6 inches across, is placed in front of it, and by the simple movement of a handle the saw glides forward, and in 15 seconds the log is cut in two. A frame with 30 saw blades, moving up and down at a uniform speed, divides a pine tree, 2 feet square and 25 feet long, into 29 planks in less than half an hour. Rough boards, 15 feet long and 7 inches wide, are pushed in rapid succession through a machine with revolving cutters, which planes them quite smooth on both sides and cuts a tongue on one edge and a groove on the other in one operation at the rate of 50 feet per minute; 450 miles of boards and battens have passed through one such machine in twelve months. It would take a carpenter about 45 minutes to plane a single board of the same dimensions in the same way by hand, so that the machine may be said to do the work of about 50 carpenters.

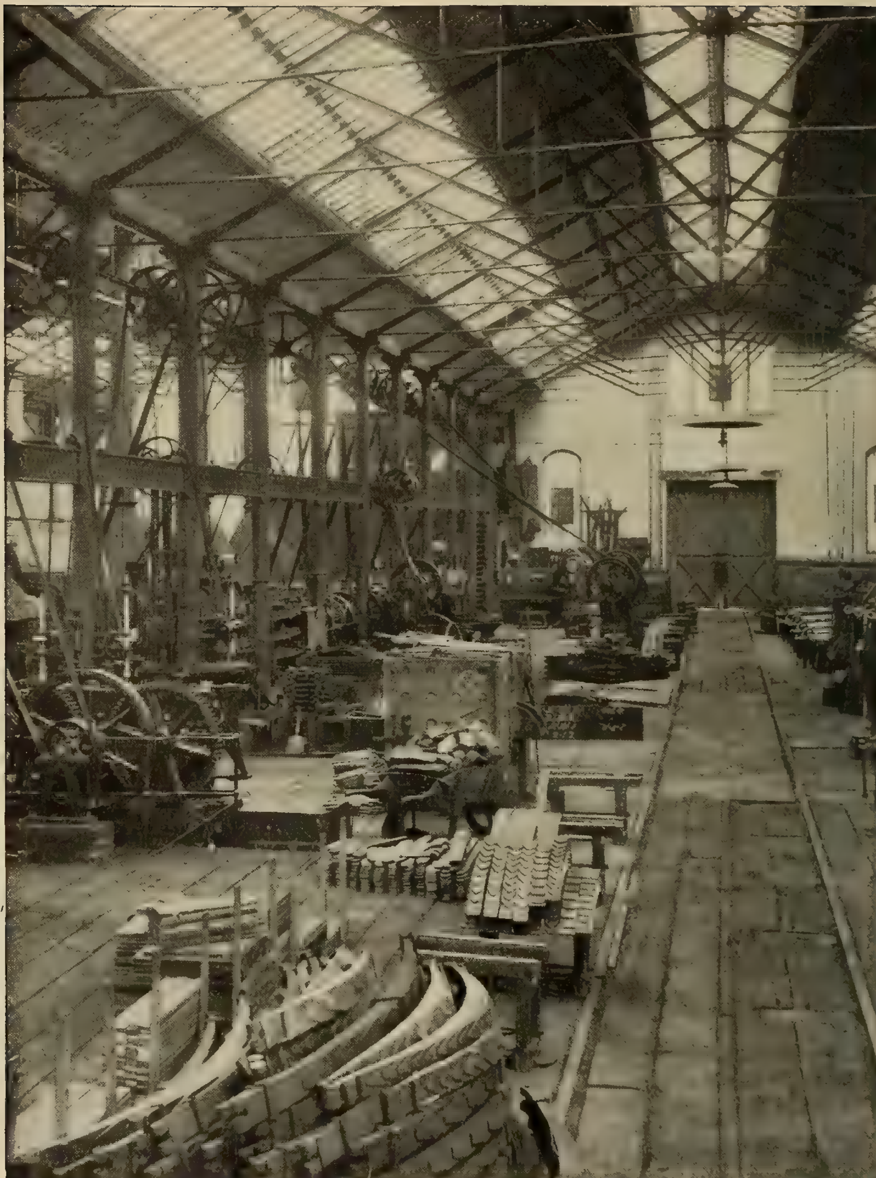
Just above the surface of a plain iron table is a steel cutter spinning at an incredible speed. A mahogany board is laid flat on the table and its edge pushed along the cutter. It is obscured for a few seconds in a thick cloud of fine shavings and reappears in the form of a panel, with perfectly moulded edges, to be used in the decoration of a first class carriage. Boring and mortising machines with vertical drills and reciprocating chisels, cut round or square holes, up to three inches through timber 16 inches thick, with the greatest facility.

The scrap and short ends of oak, which are too small for use in carriage and waggon building, are utilised for making the keys which secure the rails to the chairs of the permanent way. They are cut by a circular saw into pieces about 7 × 3 × 2 inches, then pressed through a moulding machine which turns them out at a rapid rate to the exact form required, with one edge bevelled, one rounded and one face

CUTTING CARRIAGE CLOTH BY BAND SAW.

slightly curved. About 700,000 of these oak keys are made in twelve months.

Besides numerous wood-cutting lathes of the ordinary pattern, there are several special lathes for making the pick and hammer shafts so extensively used on the line. These have not only to be cut oval in section, but to a varying thickness throughout their length.



THE SPRING SHOP.

A hammer shaft, 15 inches long, is turned in less than a minute. The shafts thus shaped are handed over to a boy, who rubs them on a leather belt, coated with glass dust and glue, running over two pulleys. This smooths them at the rate of 4 or 5 per minute.

An ingenious little machine grasps an ordinary three-cornered file, just as a skilled workman would lay hold of it, and mechanically sharpens each tooth of a steel saw in turn without feeling any sense of fatigue. Saws are also sharpened by revolving emery wheels.

Perhaps the most interesting of the wood-cutting machines is the one by

which the sides of boxes, drawers and packing cases can be joined together by dove-tailing, cheaper than by nailing. A board of the size required is placed on a table and held by a cramp; on the machine being set in motion, the table carrying the board travels along the front of a revolving tooth-disc which cuts dove-tailed pins and holes on the edge of the board at the rate of 20 feet per minute.

The waggon shop will hold 150 trucks. About 200 of various kinds are built or repaired in it every week. A man and a boy will, in two days, erect an ordinary Midland goods or coal waggon. All the material is brought to them in a finished state, so that it merely requires putting together. No fitting is required, as every part is made interchangeable and every hole in both wood and ironwork is drilled precisely in its right place. The wheels are put under by men exclusively engaged on that work. When erecting a waggon no two parts are fixed together without first being painted, a precaution taken to prevent rusting of the iron or rotting of the timber.

The carriage building shop has 18 lines of rails running throughout its length, and usually about 90 vehicles, in course of construction, or in all stages of renovation, may be seen there at one time; 50 or 60 coaches have been repaired and 10 new ones built weekly. The construction of a coach is, of course, a more elaborate process than the building of a waggon; consequently, there is a greater division of labour. As in the case of a waggon, all the wood and ironwork for a coach comes into the shop in a finished state. Ordinarily four coach makers and two apprentices work together; they will build a six-wheeled third-class carriage, with five compartments, in three weeks. The coach builders erect the body and put the frame together; the interior has afterwards to be finished by cabinet-makers and upholsterers.

In this shop the carriages are fitted with the automatic vacuum brake in use on the Midland Railway. It stops the train by the application of brake-blocks to the wheel-tires by atmospheric pressure acting on a piston in a cylinder under each vehicle. A pipe, extending throughout the train, connects all the cylinders with an ejector on the engine. While the train is running, the ejector sucks the air out of the train pipe and cylinders by an annular jet of steam, and maintains a vacuum of about 20 inches on both sides of the pistons. In that condition, the brake remains off.

To apply the brake, the driver on the engine, or the guard in his van, opens a valve which allows air to flow through the train pipe to the bottom side of the piston, the vacuum on the top side being still maintained by the action of a little ball valve at the foot of each cylinder. The effect of this admission of air is to lift the pistons which, operating on levers, pull the brake blocks sharply against the tires and hold them there until they are released by driver or guard closing the air valve and allowing the vacuum to be restored by the ejector. The train pipe is connected between each two vehicles by a universal coupling, used by all the railway companies, which have adopted the vacuum brake. A train running at 50 miles per hour can be stopped by the vacuum brake in a space of about 250 yards in 18 seconds. In the event of the train becoming divided, the brake applies itself automatically and promptly stops both parts.

The carriage lifting shop accommodates 50 vehicles. Here wheels are taken from under carriages in order that the tires may be turned up and the axles and axle-boxes refitted. The carriages are raised from their bogie-trucks by hydraulic rams let into the floor just outside the lines of rails, as shown in the illustration on page 216. Each pair of rams will lift 10 tons. The bogie trucks, which are constructed wholly of metal, usually take a much longer time to repair than the wooden bogies of the carriages, so they are at once removed by the hydraulic lifts, overhead, and other newly repaired bogie trucks substituted for them. By this method vehicles which would

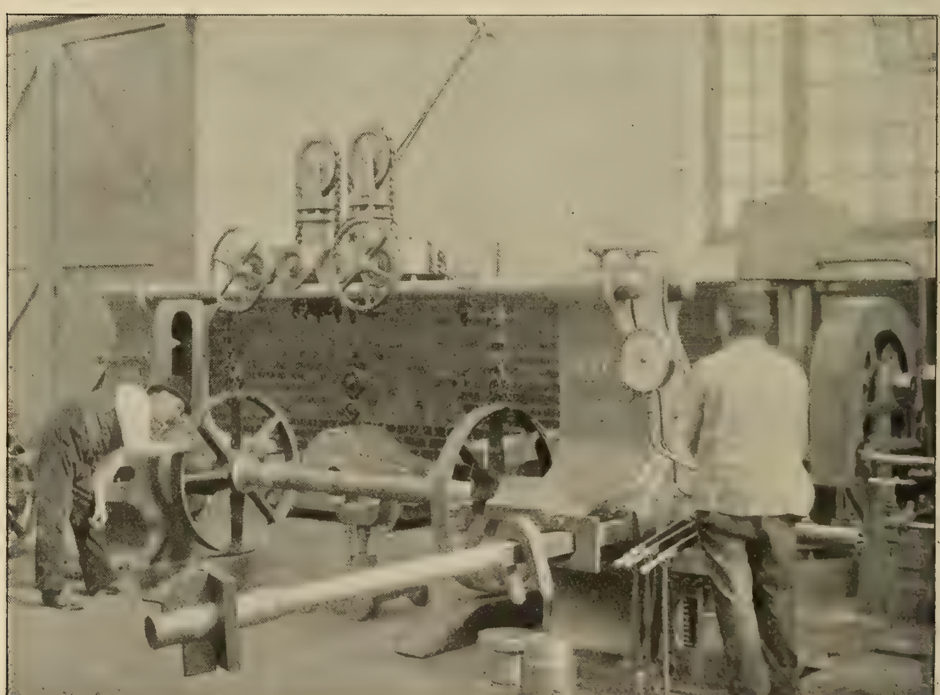
otherwise remain in the shops for days, are frequently repaired and again used for traffic in a few hours. All these lifts are actuated by hydraulic pressure of 1000 pounds per square inch.

The two paint shops hold about 280 carriages, and 50 carriages are painted or touched up in them every week. A new coach has to undergo no less than 25 operations of priming, filling up, rubbing down, painting, varnishing, etc., before it can be pronounced fit to meet the public gaze and resist the action of the weather. The paint is issued from a store in the shop, and at the close of the day, all cans, brushes, and surplus materials are returned to the stores where they are made ready for use on the following day.

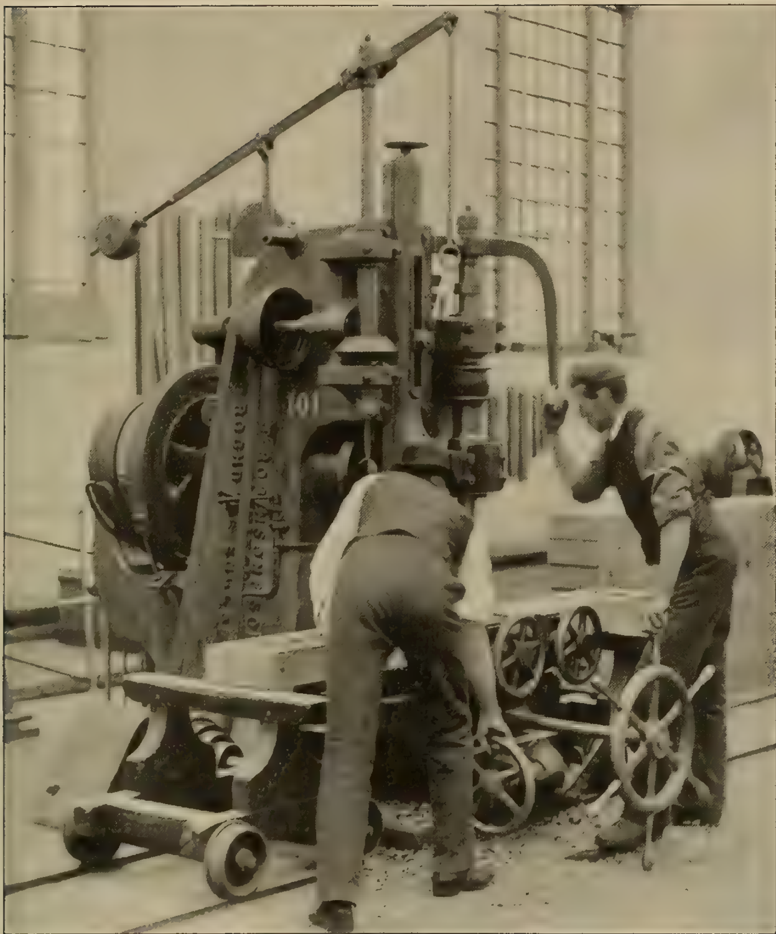
In the upholstering department the employees are chiefly girls and women, daughters of men in the factory, or widows of those who have died in the service. Their work consists of stuffing the cushions and backs of carriages, sewing window blinds, making netting for umbrella racks, polishing panels, lacquering door handles and other light brass work, washing and mangling old carriage mats, etc. The cutting out of all kinds of material is greatly facilitated by a special machine in which an endless, sharp, steel band, running over large pulleys and through a slot in an iron table, will cut from 50 to 100 thicknesses of cloth at a time to any required shape more cleanly and rapidly than if done, singly, by hand, with scissors.

Two cupolas in the foundry are used for melting iron. A hydraulic hoist lifts a truck load of iron or coke, 8 or 10 tons at a time, to the elevated stage from which the cupolas are fed. About 120 tons of metal are melted every week. In the brass foundry a gas furnace under the floor heats 12 crucibles at a time. Here, as in the iron foundry, special moulding machines are extensively used for certain classes of work.

In the forge, 13 steam hammers, from five to thirty cwts. each, are



PRESSING WHEELS ON AXLES BY HYDRAULIC POWER.



ONE OF THE MORTISING MACHINES.

thumping away. Two of the largest are constantly at work forging carriage and waggon buffers. Each of these hammers is served by a gang of five,— a hammer man, helper, furnace man, a youth to drive the hammer, and a boy whose principal duty it is to open and close the furnace door. All are paid by piece work, and the hammer man has charge of the gang. The gang will forge about 30 buffers per day.

Several of the most powerful hydraulic machines in the works are to be found in the forge. One draws off tires from old wheels with a pull of 200 tons. Another thrusts new wheels on, or draws old wheels off their axles. A third is devoted to breaking up old carriage and wagon axles—4 to 5 inches diameter—which it appears to do with no more effort than one would exert in snapping a stick of sealing wax. In a fourth, iron plates, three feet long and two feet wide, are bent cold, at right angles, along their whole length, to form the corner plates of coal trucks.

In the smithy are five rows of hearths, nearly 100 in all, and numerous steam hammers and hydraulic presses, besides shearing, punching, and nut and bolt making machines. In one week 7 tons of nuts, large and small, are made by three machines, and 85,000 bolts,

IN THE SMITHY.

weighing altogether about 26 tons, by seven other machines. Red hot bars of iron are thrust rapidly into these machines and forthwith nuts and bolts drop out of them, perfectly made, almost as fast as they can be counted.

The spring shop is furnished with every needful appliance for turning out good work with despatch. The steel plates are cut into lengths, and their ends spear-shaped, tapered, slotted, nibbed and punched without heating. They are then bent hot in hydraulic presses to the standard curve, tempered and put together by hand, and hooped by machinery. Finally the weight which each spring will safely carry is tested to a nicety. About 325 buffer and 500 bearing springs are made weekly.

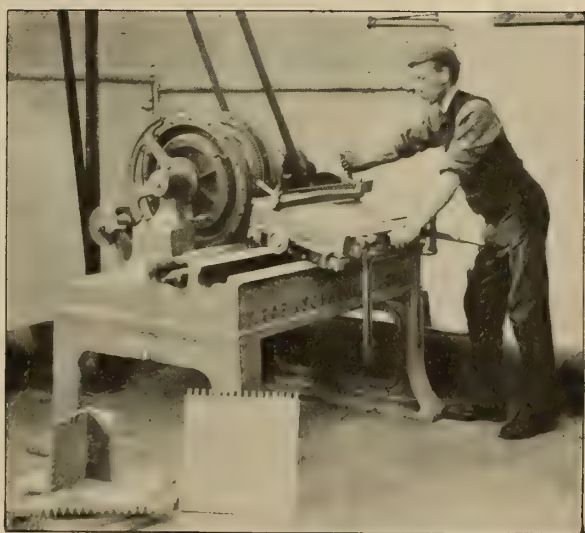
It will be readily understood that with such a large stock of trucks (115,809) the making of wrought iron waggon wheels is an important item. The operation is as follows:—A bar of iron, half round in section, 8 feet long, is heated to a red heat and gripped at one end by a revolving cylinder which instantly coils it into a ring, thus forming the rim of the wheel. The spokes are

forged out of scrap iron under a steam hammer, and each is welded in turn to the rim by hydraulic pressure.

The boss or centre of the wheel is formed by slipping in wedges between the inner ends of the spokes and welding an iron ring on either side. The welding is done under a hydraulic press which commences to embrace the boss with a comparatively gentle squeeze of 250 tons, gradually increasing it until its final hug represents a pressure of 1000 tons. While this is going on, a small hydraulic ram rises under the press and punches a hole right through the centre. The wheels, forged in this way, have their rims turned true on the outside and the hole in the centre bored out to the exact size of the axle. Each pair of wheels is then thrust on to the axle by hydraulic pressure.

The next process is to put on the tires. These are bored inside to a diameter slightly less than the rim of the wheel. They are then put into shallow circular ovens with gas jets burning all round them, and are heated until they have expanded sufficiently to pass over the rim of the wheel. In cooling, they shrink and grasp the wheel tightly. They are further secured by a retaining hoop which will prevent pieces of the tire from flying off the wheel if it should break when running. A broken tire was a frequent cause of derailment of vehicles before this method was adopted, whereas now it is a rare occurrence. Finally each pair of wheels, fixed on the axle, is lifted into a lathe, and the tires are turned true to gauge. About 200 wheels are forged each week.

In the machine and fitting shop all forgings and castings are made ready for transmission to the erecting and repairing shops. It contains 300 fixed tools of various kinds, including 125 lathes, besides drilling, planing, slotting, milling, centring, punching and shearing machines and hydraulic presses. The carriage tire-lathes have each four tools which turn the tread of both tires and face them inside simultaneously. A hydraulic crane swings over each wheel-lathe to lift the wheels in and out. Wheel tires sometimes become so hard on the surface by the repeated application of the brake that the hardest steel tools will not turn them up. To meet this difficulty, a lathe has been constructed with a pair of emery wheels which grind the tires true instead of paring them. Thirty-eight machines are at work screwing and tapping bolts and nuts at the rate of 1200 tons of bolts and 300 tons of nuts per annum. A single machine will, in one week, screw the threads on about 7000 bolts, or tap the threads inside 20,000 nuts.



ONE OF THE DOVE-TAILING MACHINES.

The Midland standard carriage wheel has the space between the boss of the wheel and its tire completely filled up by teak wood in place of iron spokes, as in the waggon wheels, the object being to deaden the sound and contribute to the easy running of the

vehicles. The teak is cut into triangular segments by specially designed saws. It is of the utmost importance that every pair of wheels should be evenly balanced; if not, oscillation is set up when running at high speeds, which, being communicated to the carriage, causes it to ride uneasily. The balancing of the wheels is tested by making them revolve at high speed while suspended on very sensitive springs. If, owing to some of the teak segments being heavier than others, there is any undue weight on one side of the wheel, it is at once indicated by the violent vibration of the springs, and the heavy side is then counterbalanced by bolting strips of iron to the segments on the opposite side.

The last shop is devoted to the breaking up of worn-out waggons. None of the old material is wasted. All the iron work which is worth keeping, is carefully sorted out and piled up in separate heaps to be used again in repairing other waggons. The scrap wrought iron is worked up into new material under the steam hammers, the scrap castings are melted down in the foundry, and the timber is sold as firewood. The total number of men employed in the works is about 3620.

Eleven steam engines and one gas engine are used to drive the machinery and provide power for the hydraulic lifts and presses so largely used in the works; and four steam traversing tables are constantly engaged moving vehicles from one shop to another.

The shops are commodious, well lighted, ventilated and warmed. There is a studied regard to method in all the arrangements. The system of piece work is almost universal, and machinery is used wherever practicable. Each branch of the establishment is, as far as possible, worked independently under the superintendence of a chief and assistant foreman, subject, of course, to the control of the works

CARRIAGE TRIMMERS AT WORK.

A MIDLAND RAILWAY DINING CAR INTERIOR

manager and the chief of the department. New carriages can be turned out of the shops at the rate of one per day, and new waggons at the rate of one every twenty minutes.

The offices comprise two blocks. The principal one is for the superintendent of the department and his staff of clerks. Here the whole of the business correspondence is conducted, the general accounts are kept and pay bills made out. In the draughting office, which forms part of the same building, vehicles of all kinds are designed, working drawings prepared and specifications got out under the direction of the superintendent. The other block of offices is occupied by the works manager, his clerks and timekeepers.

The total coaching stock of the Mid-

A DINING CAR KITCHEN

land Railway Company at the end of the year 1896 numbered 4745, and the waggon stock 116,082. These, placed in a line, buffer to buffer, would reach 420 miles. Besides ordinary carriages and waggons, the figures include a miscellaneous collection of vehicles, of which the following are examples:—Drawing room, dining and sleeping carriages; travelling post-offices, horse boxes, prize, cattle and hound vans; newspaper, parcels, fruit, meat, milk, bullion, gunpowder and corpse vans; cattle, fish, and carriage trucks; refrigerator-meat vans, waggons for rails, ballast, sleepers, armour plates, engine boilers, tramcars, traction engines, girders, plate glass, and large pulleys; also timber trucks, creosote trucks, coke waggons, etc. All these are specially constructed to meet the requirements of the various classes of traffic named.

Some idea may be formed of the unusual facilities given to traders under certain circumstances from the fact that on several occasions special trains with three 40-ton trucks, coupled together, have been placed at the disposal of one firm for the carriage of heavy guns from Sheffield to London, and trains have been marshalled consisting of 5 trucks, each 30 feet long, to carry some miles of submarine cables.

In addition to the large number of men in the works at Derby, 2300 are employed at twenty other depots on the line, where repairs are made to carriages and waggons. In the wheelwright's shops at Kentish Town are repaired the 1000 London carting vehicles and omnibuses belonging to the Midland Company.

In the works at Derby were constructed the first and third-class dining carriages which run daily on the Midland express trains, leaving St. Pancras at 10.30 A. M. and 2.10 P. M., and Glasgow at 10 A. M. and 1.30 P. M. These carriages are 60 feet long and 8 feet wide. They have steel under frames and bodies framed with oak and panelled with Honduras mahogany. They are carried on two six-wheeled bogie trucks which enable them to run

round sharp curves without lurching. Each carriage weighs 33 tons. Communication is established between the first and third-class carriages by means of a flexible gangway for the use of the attendants only.

The first-class carriage contains a general saloon with twelve seats, a smoking saloon with nine seats, two lavatories, a pantry, kitchen, and luggage compartment. The interior of the saloon is finished with American walnut and the ceilings are richly painted and decorated. The seats are upholstered with crimson morocco leather, and are arranged transversely at either side of a central gangway, so that there is a separate seat for each person. The tables are removable and can be readily fixed between each pair of seats before dinner is served. Electric bells are within easy reach of the passengers. The pantry is fitted up with cupboards for glass, table linen, provisions, wines, etc., and also contains a sink with hot and cold water for washing crockery and glass. In the kitchen, which serves both carriages, is a large cooking range and boiler, heated by gas, a refrigerator, and a carving table. Cooking can be done for 60 persons at one time.

The third-class carriage is of the same size and construction as the first-class, but the dining compartment will hold thirty, and the smoking compartment thirteen persons. It also has two separate lavatories, attendants' room, pantry, and luggage compartment. The gangway in this saloon is a little off the centre, so that there are double seats on one side, and single seats on the other. The interior is upholstered with crimson plush rep. In the pantry and attendants' compartment of the third-class carriage there are more cupboards for crockery, provisions, etc., a boiler, a hot-plate for keeping dishes warm, a grill for chops and steaks, and another refrigerator. The carriages throughout the train are lighted by compressed oil gas, heated by hot water pipes, and fitted with the automatic vacuum brake.

The dining carriages recently put on the trains running between St. Pancras and Manchester (Central) are somewhat similar to those on the Scotch service, but more sumptuously furnished. Special care has been taken to minimise the noise and rattle, inseparable from rapid locomotion, by introducing India rubber springs under the bodies, padding the floors and sides with felting and doubly glazing the windows.

ELECTRIC POWER IN THE MACHINE SHOP.

Its Present Status in the United States.

By E. H. Mullin.

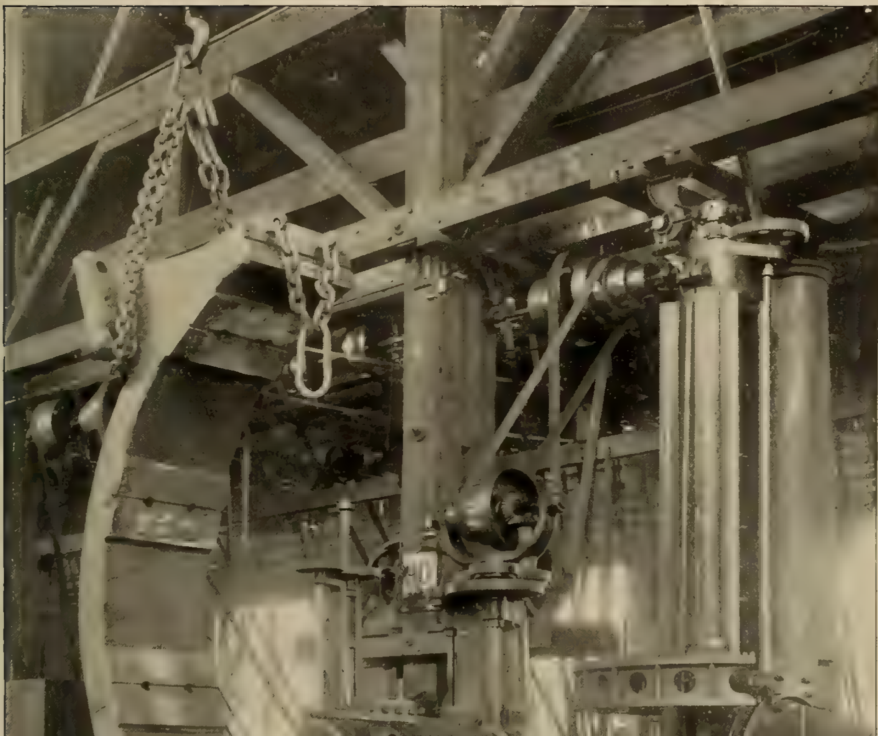
NO more remarkable expansion of the use of electricity has ever been witnessed than its application, during the past three or four years, to the driving of tools in machine shops. We are all too sadly familiar with the treatises and articles published six or seven years ago by the so-called friends of electrical development, in which they showed how tools could be so driven and in which they proclaimed the enormous advantages of electricity in such cases over every other form of motive power.

The writers of these articles would to-day, if they were candid, frankly acknowledge that they inspired business men with a profound distrust of electricty as a motive power, because when these business men began to go into details, after their fashion, they found that the current was, at that time, much more expensive than direct steam or regular belting, while those of them who actually installed plants with electric motors, found that the motors had an unfortunate habit of breaking down at the most unexpected and embarrassing times. In one word, the time was not ripe.

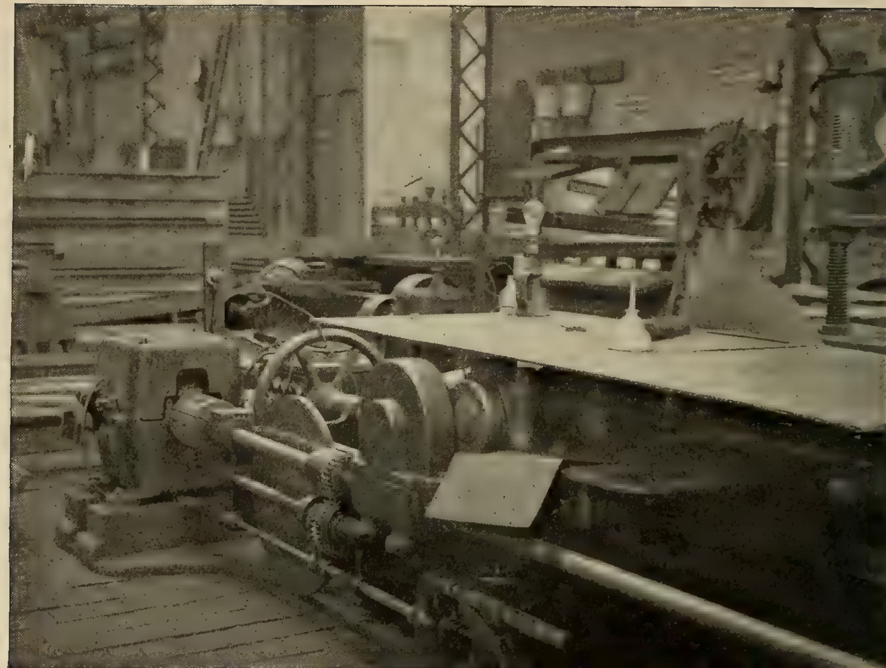
Since then, however, the vast extension of the trolley system and the consequent experience which it entailed, directly and indirectly, on manufacturers of electric motors everywhere, have made it possible to build motors of any size, which, with an economical output at a given load, will stand occasional or frequent overloads with impunity.

It has long been known that ordinary belting and shafting are a most uneconomical means of transmitting power. Where the aggregate horse-power conveyed through one main belt was large, the subdivisions numerous and the area over which they extended comparatively large, this loss between steam cylinder and tool has frequently risen as high as eighty per cent. A fair average for the belted machine shops of to-day, in running order and not too new, would be fifty per cent. of the whole power consumed. But even these were not all the losses. To tighten the main belt meant to stop the whole work of the shop until the job was accomplished. To tighten a section belt meant stopping the work of that section. Who can calculate the money time thus lost while the men stood idly by?

Moreover, in the nature of things, the main belt, entering from the engine room, was almost invariably at one end of the shop, thus necessitating a long line of shafting to which the unbalanced motion must be given at one end. In a large machine shop at Lynn, Mass., a steel countershaft, 2¾ inches in diameter and 275 feet in length, was turned at the power end from rest to one-quarter turn before the distant end of the shaft showed any perceptible sign of motion. Any one, upon reflection, will see that this constant spring thrust of the shaft must have added considerably to the difficulty of keeping the bearings in true alignment as well as adding constantly to the friction losses. The modern travelling crane, which



THE OLD WAY OF DRILLING A CASTING IN THE SHOPS OF THE GENERAL ELECTRIC CO, AT SCHENECTADY N. Y. THE NEW WAY WITH THE SAME CASTING IS SHOWN ON PAGE 246.



GENERAL ELECTRIC CO. MOTOR COUPLED DIRECT TO A COLD SAWING MACHINE AT THE WORKS OF MESSRS. WM. WHARTON, JR., & CO., LTD., PHILADELPHIA.

runs the whole length of shops where the individual pieces of work are heavy, has increased the difficulty of putting belting in every part of the shop, since in that case all belting crossing the path of the crane has to be carried up overhead.

These obstacles and drawbacks to belting a large shop throughout are thus described because they form the key to the recent expansion in the use of electrically-driven tools. In other words, when a more convenient substitute was forthcoming, the owners of large shops who had capital and enterprise, and who realised the waste of power which complete belting must always entail, were ready to take advantage of it.

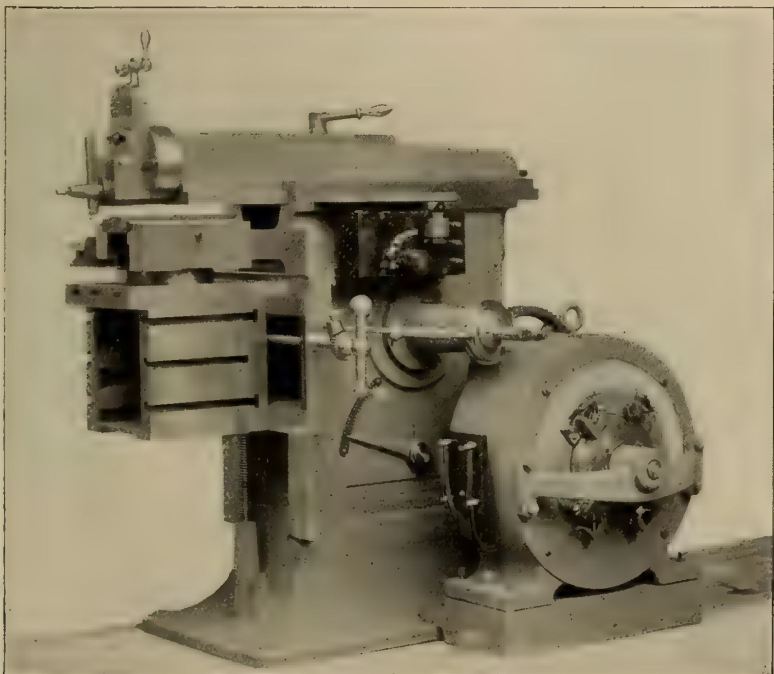
Of all the merits of electrical power, the ease with which it can be distributed is the most remarkable. Nine-tenths of all the fires which occur in large shops and factories come from the boiler house. But under any economical system of belting it was necessary that the boiler house and engine room should be situated close to the shops, and in the case of several shops, placed some distance apart, that each should have its own steam plant. It was satisfactory, therefore, to both owners and insurers that a means had been found by which the dangerous boiler house could be placed where its possible conflagration would be without risk to the adjacent buildings. This has given a great impetus to the introduction of electrically-driven tools wherever shops have recently been burned down.

In the case of several shops placed widely apart, it was also soon seen that the use of electricity permitted the grouping of the entire steam plant under one roof, thus saving the annoyance of auxiliary engines with independent boilers or with the wasteful use of steam through condensation, coming, as it did, through long lines of piping, as well as enabling work to be done by mechani-

cal power which had previously to be done by hand power. A good illustration of this last fact, which may be mentioned in passing and which will be dealt with more fully later, is afforded by a derrick crane in the yards of a prominent firm of architectural iron workers. Before this crane was fitted with electricity, the steam engine which ran it afforded no means of swinging the arm over the object to be hoisted. The consequence was that the services of two or three men were required every time this operation had to be done. Electricity now turns the arm at an estimated saving of $3 (12 sh.) a day.

Rome was not built in a day and the introduction of electrically-driven tools has not come in a moment or sprung full fledged and complete into its latest state of development. There have been three stages in the introduction of electricity into the machine shop, and, while the last seems the most logical, it is not at all settled yet whether it is the most economical. Economy, of course, is true test of survivorship. These three stages, with some limitations, to be explained further on, have been as follows:—First, the substitution of electricity for the main driving belts, or for section driving belts; second, the attaching of the motor to the tool in such a manner that it revolved the main shaft by a gearing. Thirdly, building the armature of the motor on the main shaft and concentric with it, so that it revolved without gearing.

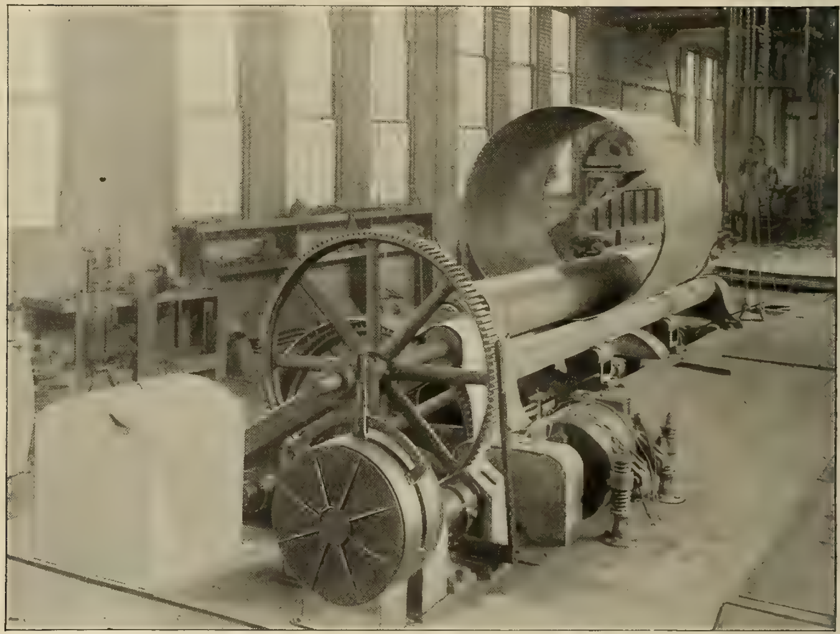
Edison, judging from conversations which the writer has had with him on analogous subjects, would probably look upon the third stage as being the most likely to triumph in the long run since he believes that the power and the active member of any machine should be as closely and indissolubly connected as possible. There is no doubt that convenient and economical motors, from one-eighth, or even one-sixteenth of a horse-power, to fifty horse-power, could



A DIRECT CONNECTED SHAPING MACHINE AND MOTOR, FITTED UP BY THE BULLOCK ELECTRIC MFG. CO., NEW YORK.

be made and fitted so that their armatures would be in one with the driving shaft or spindle of any tool, and we could certainly all admire the compactness, noiselessness and handiness of such a tool. But the case of arc versus incandescent lamps in regard to cost, shows us that there must always be some waste in each subdivision of the electric current, since in spite of the very perfect three-wire system of distributing current to incandescent lamps, arc lamps are much cheaper in consumption of current. Moreover, we have had, in recent years, two great illustrations, one technical, the other popular, of a reaction from direct action to gearing which teach us to beware of theorising on the matter. The first of these was the universal adoption of single-reduction gear for trolley motors after direct torque of the armature on the axle had been extensively tried. The other, or popular one, is the success of the safety bicycle after high-wheel, direct-acting bicycles had been in use for many years without producing much impression.

Turning now to the first stage of the introduction of electricity into the machine shop—that is, its substitution for main or section belting—we find as its first advantage that the motor, with its armature spindle bearing a pulley to belt with the countershaft, can be placed up on the ceiling, on a side wall, on a pillar, or on the ground, as convenience dictates. This also allows the pulley on the countershaft to be placed where its action will be balanced to the best advantage. Thus, with, say, ten tools, requiring average equal horse-power, the power will be placed so as to act at a point near the middle of the countershaft, reducing the friction on the most distant bearings, and giving a more equable and economical distribution.

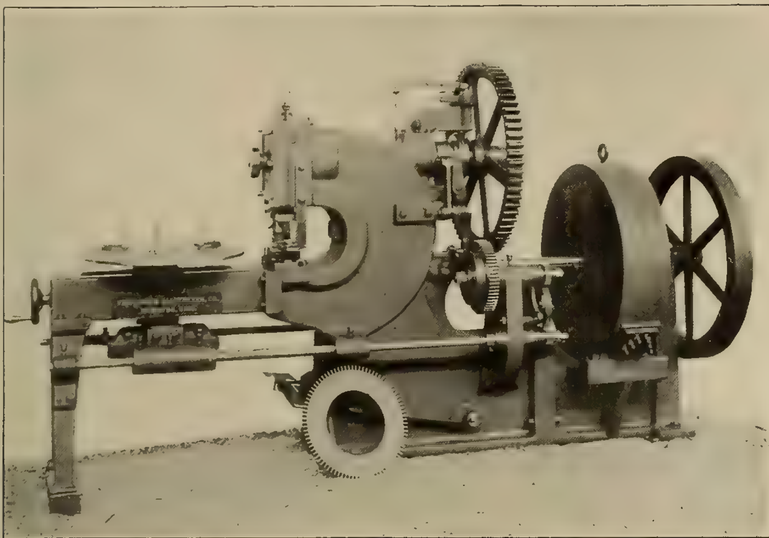


BENDING ROLLS IN THE BOILER SHOP OF THE AULTMAN & TAYLOR MACHINERY CO., MANSFIELD, O., DRIVEN BY AN ELECTRIC MOTOR SUPPLIED BY THE CARD ELECTRIC CO., OF MANSFIELD.

Then, again, with belting it is not always possible to cut out any countershaft in the shop because the series of connections entail that the whole plant must run if a single man in the farthest end of the shop wishes to drill a half-inch hole. But with electric motors the shop may be divided off into convenient sections, each countershaft hav-

ing an independent motor, so that if men have to work overtime in one part of the shop, the rest of it can be closed down with no loss of power and with a smaller consumption of steam from the boiler.

This is the plan substantially adopted

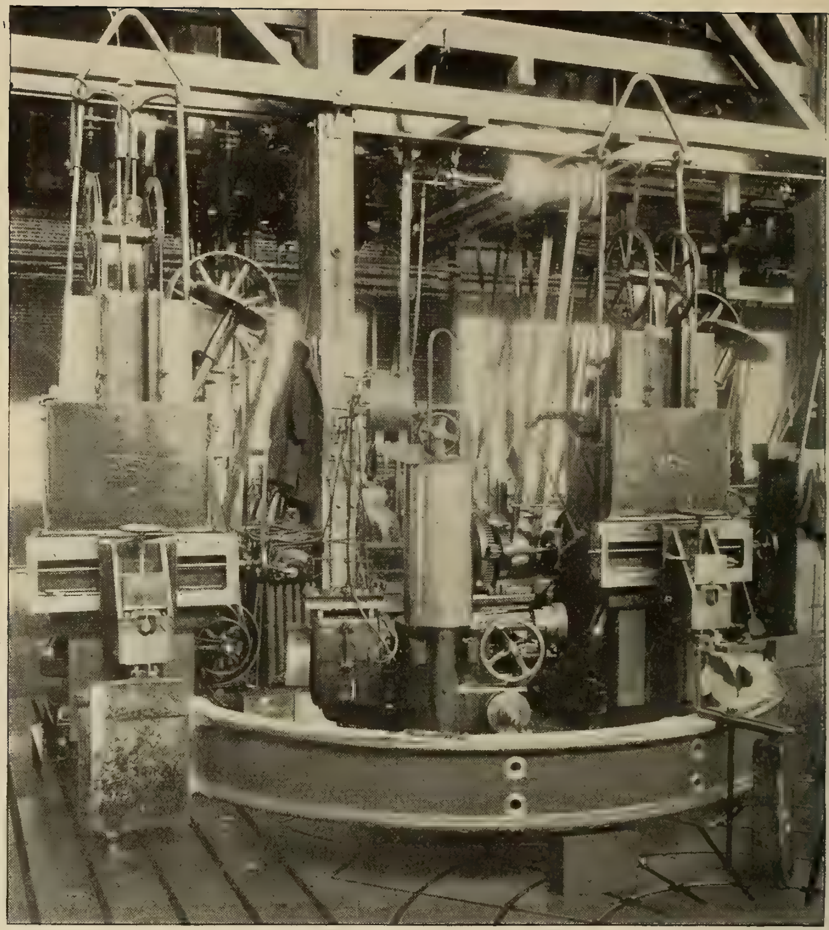


A LONG & ALSTATTER PUNCH, DRIVEN BY A BULLOCK MOTOR.

in the great works of the General Electric Company at Schenectady, N. Y. At least twenty-one shops there, widely scattered apart, have machine tools installed in them. It is, perhaps, well to remember that, in the making, electrical apparatus has nothing to do with electricity. The field rings are massive pieces of cast-iron or cast steel which must be bored out until the bases for the field magnets are perfectly true segments of a circle. The holes for the bolts which connect the pole magnets to the field ring must be drilled equally true. The sheet steel or iron discs for the armature core have, in like manner, to be stamped out with a castellated border so as to receive the loops of the armature coil. Only when it comes to the insulation of the copper wire does an element foreign to most machine shops enter into the process. The final end of all electrical work is its thoroughness and accuracy, and while the apparatus is built up from prepared designs as in any other machine shop, it must be put through the severest of all tests—its capacity in registered volts and ampères—before being shipped to its destination.

The works of the General Electric Company should therefore show us how electricity is employed in the machine shop by those who have an exceptional right to judge of its economical use. The general features are a 3000 horse-power steam plant which has its energy converted into current at pressures of either 220 or 500 volts. This current is led by insulated underground cables to the widely dispersed buildings. Mr. John Riddell, who has charge of all the machine tools and who conducted the writer through the buildings, explained to him the general plan of action. Tools of the same size, having regard to the work to be done, are grouped, as far as possible, in one shop.

Thus, where the heavy castings are finished, the large lathes, planes and borers are to be found. A 20-ton overhead crane runs the whole lenghth ot this and the adjoining shop—about 500 feet. The largest planer has the usual quick return and has a capacity of



TWO PORTABLE SLOTTING MACHINES AND A PORTABLE DRILLING MACHINE, ALL ELECTRICALLY DRIVEN, ON A LARGE CASTING IN THE SHOPS OF THE GENERAL ELECTRIC CO., AT SCHENECTADY, N. Y.

$10 \times 10 \times 20$ feet. It is run by belting off the countershaft in the usual way, the consumption of energy in the travel of the bed against the tool being 25 horse-power, and at the moment of reversing, 40 horse-power. Mr. Riddell questioned whether it would be expedient to use a direct-connected motor in such a case, as the slip of the belt at the moment of reversing toned down the shock.

In this large tool shop a practice has been in vogue which is probably the forerunner of a revolution in the use of machine tools. Where the casting is large, and where it is inexpedient to move it often, the smaller tools, such as drilling and milling machines, which have motors fixed in the tool frame itself, are brought to the casting, and as many as four of these machines have been grouped around a large casting at one time, each doing its own work irrespective of the others. In the same manner emery wheels, driven by small self-contained motors, are often employed to grind and polish portions of apparatus while other work is being done upon them.

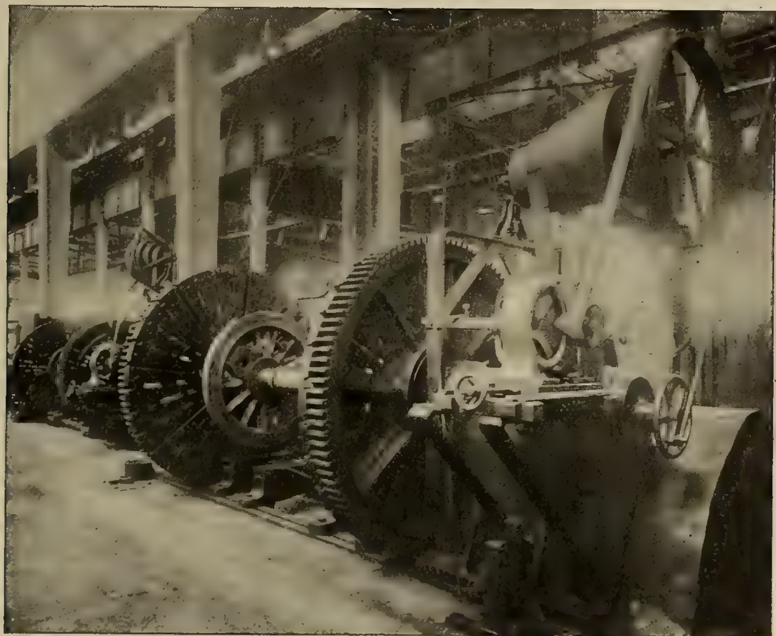
In the porcelain department of the General Electric Company's works stand, side by side, two potters' wheels. One is of wood, driven by foot power, of practically the same pattern as pre-

vailed in the Assyrian and Babylonian empires and ever since. The other is its exact reduplication in steel, without the treadle, but with an electric motor. Here stand together exemplifications of the oldest and of the newest power known to mankind; the tool is the same, only the method of driving it is different.

There are many beautiful electrically driven tools in the works of the Crocker-Wheeler Company at Ampère, New Jersey. The first of these which the writer noticed in a visit paid to the works, was an ordinay sensitive drill having the armature of the motor—a half horse-power one—in the top of the spindle and concentric with it. There was a slot in the spindle to allow comparatively free longitudinal play. Another tool in the same works was a lathe of two horse-power, having a throw of thirty-four inches and a length of fourteen feet. In this case the motor was in the headstock, not directly on the axis but geared to it.

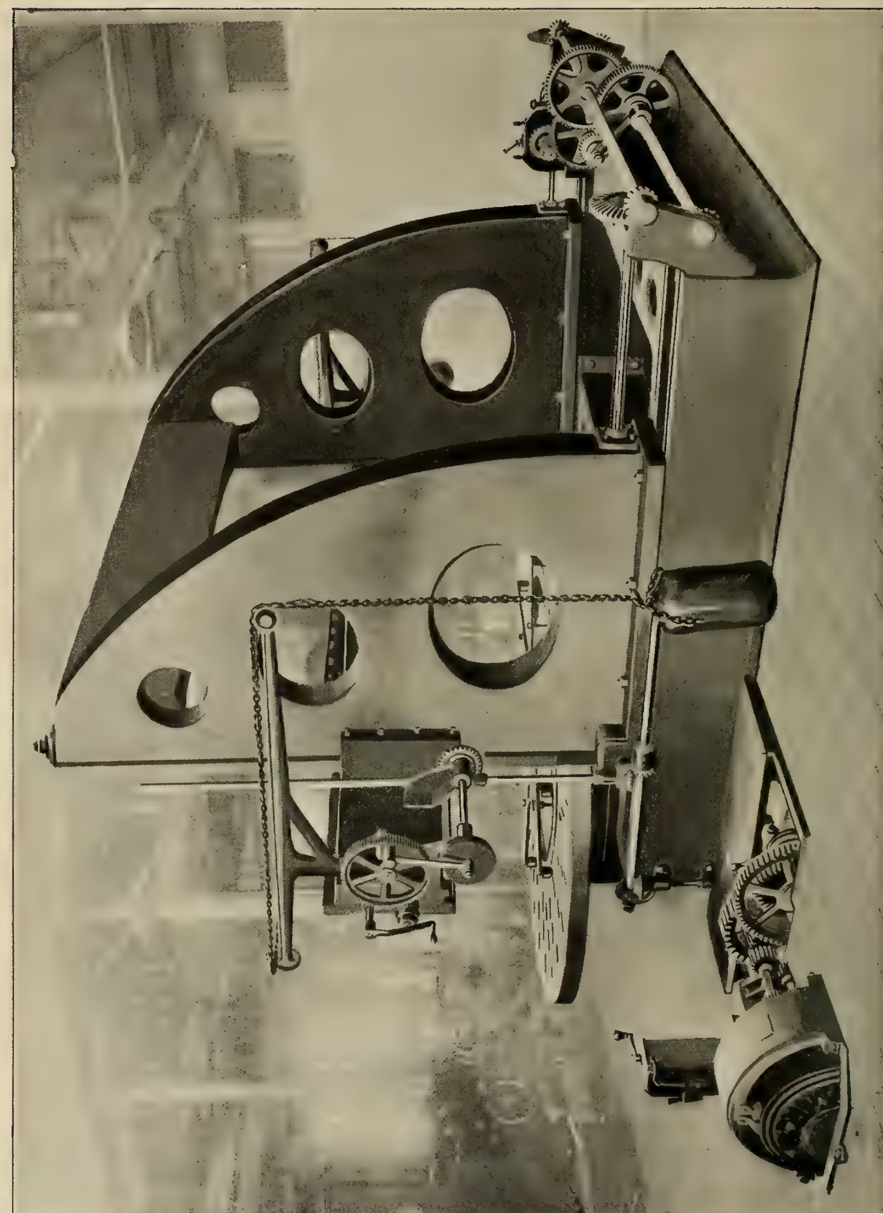
The objections to placing the armature of the motor on the main spindle of the headstock are that the speed cannot be varied by intermediate gearing and that, in many cases, it is not practicable to have a motor made to run efficiently and economically at the very slow speeds necessary to make a deep cut. In fact, for motors under ten horse-power, 100 revolutions per minute seems, at present, to be the slowest possible practicable speed.

Another and a larger lathe, beside the one just mentioned, has a swing of 52 inches and a length of 16 feet. This has a three horse-power motor geared to two sets of differential gearing, which slip out and in, so that the machine has ten different speeds to be used according to the heaviness or lightness of the work. The man in charge of this lathe told the writer that he much preferred it to the old style of belted lathe because it required less attention, always worked smoothly and steadily, and could be depended upon to give uniform results.



AN ELECTRICALLY-DRIVEN WHEEL-TURNING LATHE AT THE BALDWIN LOCOMOTIVE WORKS. AT PHILADELPHIA, EQUIPPED BY THE GIBBS ELECTRIC CO., MILWAUKEE, WIS.

In another part of the Crocker-Wheeler shop is a one horse-power



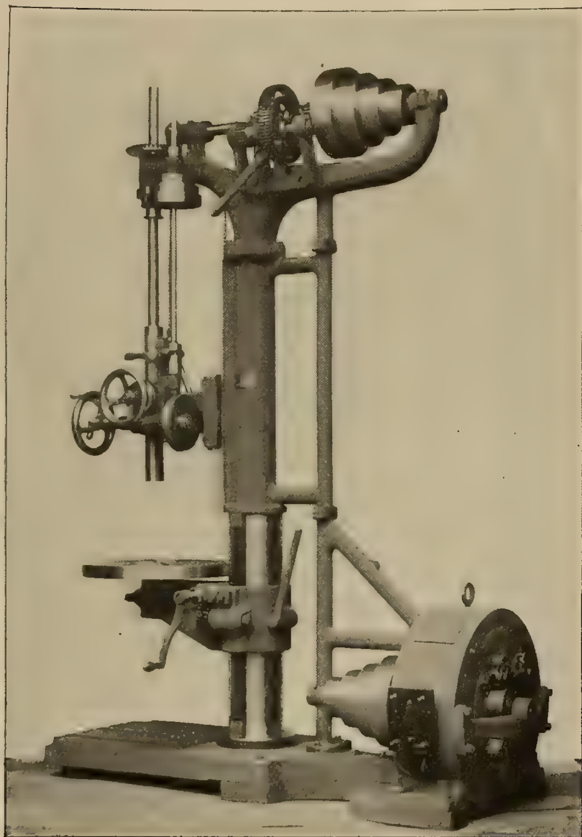
BORING MILL, BUILT BY THE BETTS MACHINE COMPANY, WILMINGTON, DEL., IN THE SHOPS OF THE CROCKER-WHEELER ELECTRIC CO., AT AMPÈRE, N. J., DRIVEN BY CROCKER-WHEELER ELECTRIC MOTORS

lathe which has the armature fixed on the axis of the headstock. By means of a controller with varying resistances, this lathe can be made to work at any given speed, though, of course, the surplus power is absorbed by the resistance box at the slower speeds. This lathe is intended for small work where starting, stopping and reversing quickly is desirable, and in the presence of the writer the tool performed all these operations with admirable quickness and smoothness.

A splendid direct-connected tool which has just been put into operation in the same shop is a big boring machine. In this case the piece of work, usually a field casting, is placed on the table and turned against the tool by an 18 horse-power motor, the armature of which is spindled on the main shaft. At the back of the machine is a small separate motor acting by gearsto shift the cutting tools after each revolution. This machine is capable of receiving a casting, 16 feet in diameter.

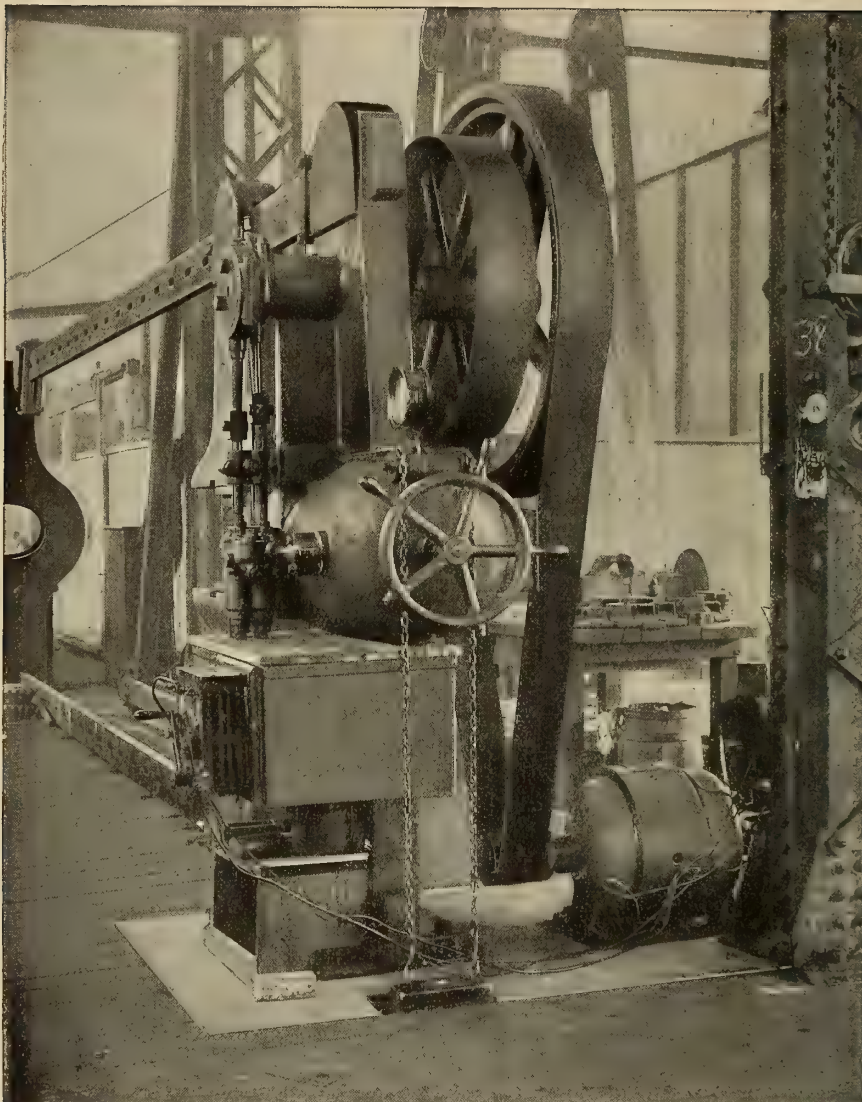
Another interesting tool in the same shop is the "notcher," or automatic punching machine for slotting armature discs. Here a half horse-power motor is fixed to a small table on the side of the tool and a belt is carried up to a pulley in the head of the tool. By means of a slotted pattern disc, of the same size as the disc to be stamped out, and an escapement movement, the slots in the circumference of the sheet steel or iron are punched out automatically and with perfect regularity. The two internal slots for fastening the disc on the armature axle are also made at the same time.

Allusion was made earlier in this article to the saving made by installing electric motors in the derrick crane at an iron works, that of Messrs. Post & McCord, at Brooklyn, N. Y. This crane is now operated by a ten horse power geared motor for the hoist and a three horse-power motor for the trolley travel. The two controller handles necessary for the operation of these motors are easily manipulated by one man, and the result, according to the account which this man gave the writer, has been highly satisfactory, the starting and stopping being much quicker than with steam and the movement more certain and uniform.



A DRILLING MACHINE DRIVEN BY A DIRECT-CONNECTED BULLOCK MOTOR.

Messrs. Post & McCord have recently changed most of their tools from belt driven to electrically driven, and the writer was informed by Mr. McCord,



ENCLOSED MOTOR DRIVING A HYDRAULIC PRESS, EQUIPPED BY THE ELWELL-PARKER ELECTRIC CO., CLEVELAND, O.

Jr., that the results are considered highly satisfactory by the firm, not only for their saving in money, which is considerable, but also, what is of equal importance in a shop where many long steel beams have to be dealt with, in allowing a free swing for these beams in any part of the shop, unimpeded by the belting which was formerly attached to the tools.

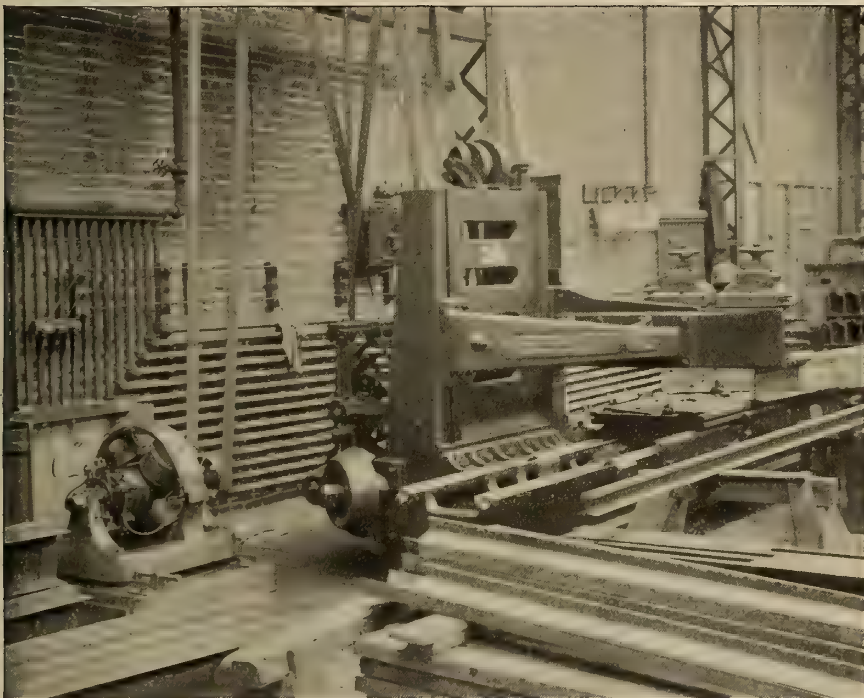
Among other electrically driven tools in these shops is a punch for making holes up to two inches in diameter in iron plate up to one inch in thickness. This is driven by a seven and a half horse-power motor geared to the main shaft of the tool. The motor is at the base of the tool and is completely boxed in, the controller handle being in front, within handy reach of the man operating the machine. To prevent the whole strain of a miss, when the punch

will not penetrate, owing to some extra thickness in the iron, from falling on the motor, a taper cone is inserted in the gearing so that it will slip from its base toward its apex when the pressure upon it exceeds a given amount.

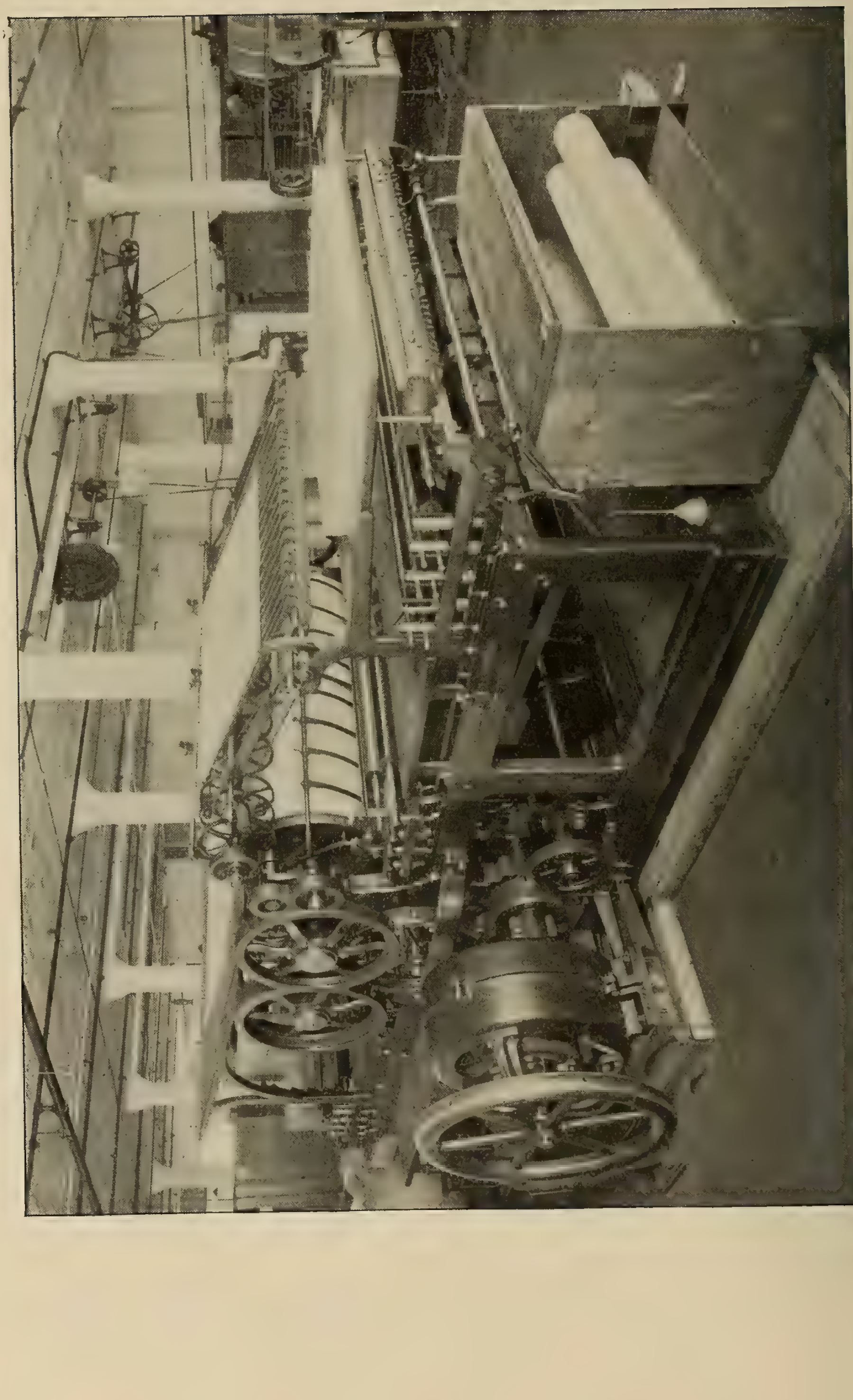
Other electrically driven tools in the same shop are angle-iron shears, driven by a ten horse-power geared motor; a six horse-power saw for cutting iron plate; and a coping machine, for preparing the ends of iron beams, which has a compressed air cushion to relieve the motor of the return shock.

The Bullock Electric Manufacturing Company, of New York, has been devoting a great deal of its energies during the past four years to the problem of making efficient direct-connected motors for machinery of all kinds, including engine tools. To this end it has been turning out slow-speed motors, varying from 1000 to 100 revolutions per minute, the plan being to fix the armature of these motors on a prolongation of the main shaft of the machine or tool. Thus, the company has fitted up lathes, multiple pipe drills, shapers, boring machines, planers and milling machines with its motors, and the results have been so satisfactory that the company believes that the direct-connected type of motor will ultimately be universally used, in large machines at all events.

Mr. R. T. Lozier, the company's manager, is inclined to think that, in the present state of electrical development, it would be more economical to group small tools, under five horse-power, and run them by belting from one overhead motor, rather than to put a direct-acting motor in each of them. But, as he adds, if a demand for small motors were to set in great enough to justify the numerous electrical companies in the country in making the necessary experiments, trials and calculations,



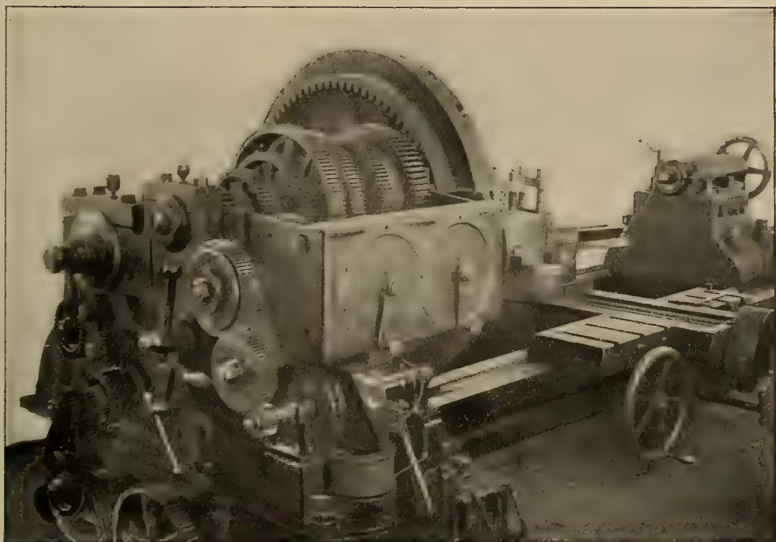
INDEPENDENT GENERAL ELECTRIC CO. MOTOR DRIVING A PLANER IN THE SHOPS OF MESSRS. WM. WHARTON, JR., & CO., LTD., PHILADELPHIA.



A LUNDELL MOTOR DIRECT-CONNECTED TO A PRINTING PRESS, INSTALLED BY THE INTERIOR CONDUIT & INSULATION CO., NEW YORK.

there is no doubt that even very small, slow-speed motors could be designed and manufactured so as to give a degree of efficiency and economy far beyond anything now in the market. The manner in which the demand for high speed electric fans was met is an analagous case in point.

The striking successes of the Bullock Company, however, has not been so much in tools—though it has done its fair share in that line—as in machines for industrial uses. While printing presses cannot be classed as tools, they resemble them in so many ways that what has been found useful and economical as a means of driving printing presses will soon be applied to shop tools with similar complicated mechanism. Four years ago it is safe to say that not a single Hoe multiple printing press, on which the largest daily newspapers are usually printed, in the United States was driven by a direct-connected slow-speed motor. To-day, in New York City alone, the *Herald*, *Sun*, *Times* and *Journal* have Bullock motors fixed to the main shaft of some or all of their presses, while the *World* has a Crocker-Wheeler motor as an auxiliary in case it should be desirable in an emergency to drive electrically. Other American cities outside of New York, such as Chicago, Philadelphia, San Francisco, Paterson and Toronto, have the same story to tell.



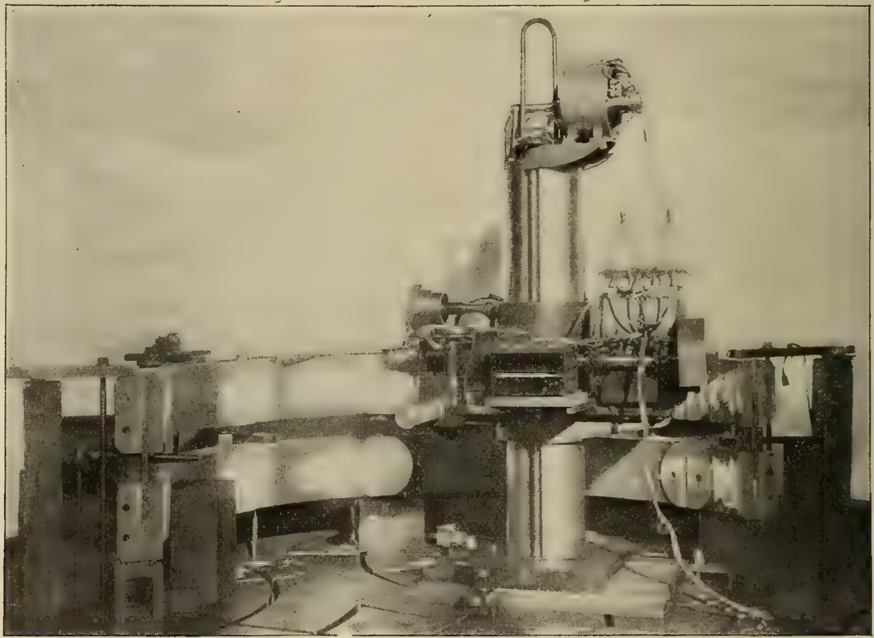
AN ELECTRICALLY DRIVEN LATHE AT THE CROCKER-WHEELER ELECTRIC CO.'S WORKS.

When it is considered that a printing press for a daily newspaper is in use only a few hours out of each twenty-four, that its output may vary within very wide limits, and that under the old system steam must be kept up and belting running for a considerable time before, and a considerable time after, the edition is actually printed, it will be seen that the starting or stopping of a press by the turning of a hand switch must result in a much more economical output of power.

Among the practical difficulties which always existed in the press room of a large daily newspaper run by belting was the fact that two men were always required to put the press in motion, if only for oiling purposes. This was because one man had always to stand by the belt to slip it on the pulley, while the other climbed up to oil bearings or to affix the semi-cylindrical stereotype plates on the printing cylinder. As the belt had only one invariable speed and as it took perceptible

time for the man at the press to call out to the man at the belt and for the man at the belt to throw it on to the idle pulley, the press was frequently turned past the desired mark and had to be put through another revolution to again reach it. The electric motor, with twenty different rates of speed between "dead slow" and full speed, and with "stop" buttons placed within reach of a man's hand in every part of the machine, has changed all this, so that what is now comfortable for one man to do was formerly a thankless job for two men to attempt together.

Just two years ago the president of the Mergenthaler Linotype Company, Mr. Philip T. Dodge, told the writer that he had carefully gone into the question of electricity *vs.* belting for an enlargement of the company's shops in Brooklyn, and that there was no doubt in his mind that belting was, at that moment, a cheaper method of conveying power to tools than electricity. A few months ago Mr. Dodge took out all the belts in the shops he controls and replaced them by direct-acting and geared motors. It has been found there by careful calculation that the



A PORTABLE ELECTRICALLY-DRIVEN BORING AND DRILLING MACHINE IN THE GENERAL ELECTRIC CO.'S SHOPS.

same steam power which formerly ran the belted plant now not only runs the electrically-driven tools, but lights the shops as well—no inconsiderable item when the light was taken off the street mains.

But not only have the daily newspaper presses, the rotary action of which resembles a high speed lathe, been fitted with electric motors, but the weekly and monthly illustrated magazines, which have flat bed presses, resembling a quick return planer, have also been similarly equipped. And the chief lesson to be derived from the facts just set forth is not that publishers prefer electricity to belting, but that they find it cheaper, for sentiment has absolutely no place in a publishing office.

The greatest direct benefits which have resulted from the introduction of electricity into the machine shop have been seen in some of the large foundries of Pennsylvania. In many of these, though plenty of steam went to waste, belting in the main shop was not prac-

A 30 H.-P. MOTOR DRIVING A LINE SHAFT IN THE SHOPS OF THE WESTINGHOUSE MACHINE CO. AT PITTSBURGH, PA.

ticable owing to the obstructions which it would have interposed to the free transfer of large castings or forgings from place to place. But this objection not applying to tools run by electricity, several of these shops have now seen their way clear to install machines in places which permit the castings or forgings to be begun and finished under the same roof. And not only have ordinary tools been thus installed, but also electric hoisters, conveyors and other similar apparatus for transporting everything, from coal and ashes to finished castings.

In one of these cases, electrical machinery was devised to undertake automatically by the process of passing in the steel at one end of a rolling mill and to bring it out as rails at the other end,—work that has always been previously done by hand. The labour-saving results in this case are hardly to be believed, but the writer was assured on the authority of one of the most responsible electric firms in the United States that this mill was able to reduce the number of its hands from 6000 to 4000 and still to increase its output 60 per cent.

In another case, an entire new system of conveying power was adopted, electricity being substituted for belting. Motors equal to 2500 horse-power were installed to run the respective groups of tools, while the outside dynamo capacity to run these 2500 horse-power motors was only 400 horse-power. It has since been found by experience that the average current taken by such of

the tools as are in operation at any one time is equal to only 300 horse-power, so that the proportion of tool power to dynamo power is about 8 to 1.

Occasionally, as when the shop has been shut down and started again suddenly, the power has fallen short until the regular routine pace of work has been regained, but a little foresight easily prevents this from happening. Now, at the lowest calculation, a belted plant would not be safe under similar conditions with less than a 1250 horse-power engine, or a proportion of 2 to 1. These results show better than anything else the gradual revolution which electricity is working in the machine shop.

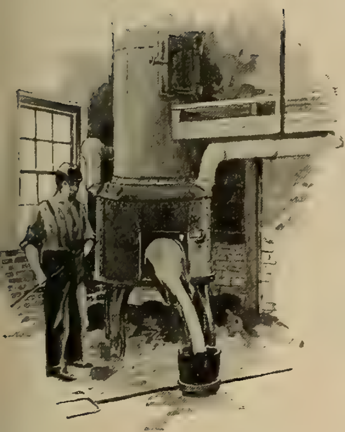
The number of firms throughout the whole United States which are daily replacing belted plants, in whole or in part, with electric motors is steadily increasing, but trade rivalries, both on the part of the electric companies which supply the apparatus and also on the part of the firms themselves which hope to steal a march on their competitors, prevent any attempt to compile a list for publication. In another year or two, when the present unorganised struggle for precedence in such work will have settled down, it will be found that electricity has become as indispensable in the machine shop as it now is in the lighting and suburban transportation fields. Indeed, as electric lighting plants increase, so will the tendency to run small shops by electricity grow, because the lighting companies will ask nothing better than to sell power during hours when the greater part of their plant would otherwise be lying idle.

To the small tool shops in the large cities electricity will prove a perfect godsend, because it will restore to them the liberty of selecting a location independent of some steam plant which has surplus power to sell to outsiders. Moreover, shops will be rearranged more in accordance with the new order of things. The necessities of belting made each tool, down to the smallest, a fixed and immovable unit to which all work had to be brought. Electricity will restore to these smaller tools their portability, so that the tool may be brought to the work and not the work to the tool, and a tool required only rarely will no longer occupy floor space when not in actual use.

A revolution is now fairly under way in the machine shop and no man knows where it will end or what changes it may accomplish.

AN INGENIOUS METALLURGICAL PROCESS.

By J. W. Meyjes.



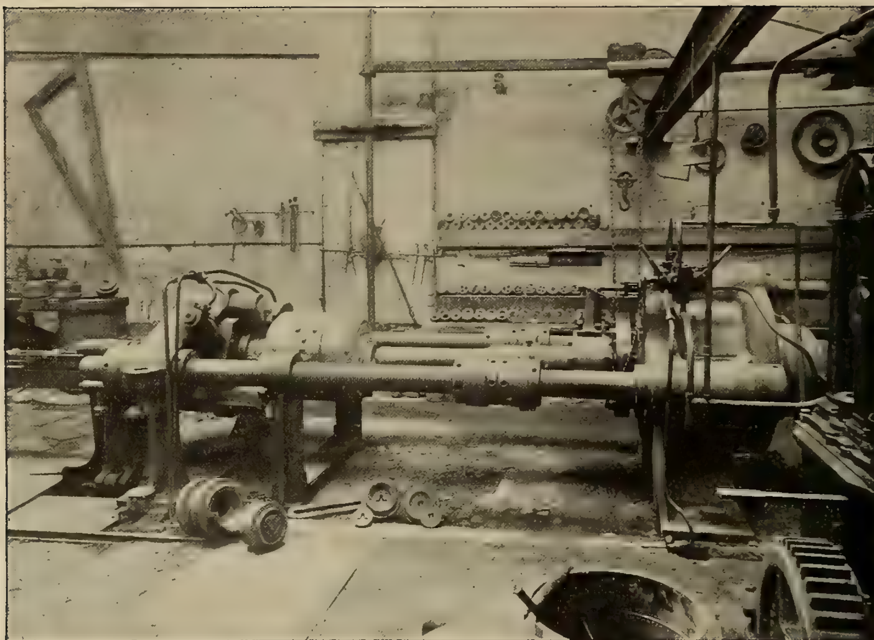
THE behaviour and flow of metals under pressure, is a subject of which, until recently, but little was known, but upon which for some time the attention of scientists has been directed. The matter was particularly interesting to Mr. Alexander Dick, the well-known metallurgist and inventor of Delta metal, who occupied himself more especially with investigations concerning the flow of metals at high temperatures, through orifices, by extrusion, and whose researches in this direction led him to believe that he might find a new and improved method for manufacturing such things as rods, pipes, and others, which, in the ordinary way, are produced by rolling or drawing.

The principle upon which Mr. Dick based his experiments was somewhat analogous to that used in the manufacture of lead tubes and rods, namely, the squirting of the heated plastic metal, contained in a vessel, through a die by means of hydraulic pressure. Various methods had already been tried to adapt this principle to the manufacture of copper and brass rods and other pieces, but without success, the chief difficulties to be solved being:—1st. How to maintain the temperature required to keep the metal in the plastic condition which was absolutely necessary for the work; 2d. How to construct a vessel sufficiently strong to resist the pressure at that temperature; and 3d. How to prevent the back flow of the plastic metal in a direction opposite to the die.

Of course, there were a good many minor difficulties to be disposed of, such as, for instance, how to get rid of the remainder, or "fag end," after the squirting operation, but the three points enumerated above were by far the most important. It is well known that iron and steel lose much of their strength when heated to redness,—cast iron as much as two-thirds, wrought iron and steel about one-third,—and when the temperature is still further raised, the loss becomes increasingly greater.

The working temperature of the metals and alloys with which Mr. Dick experimented was somewhere between 800 and 900°Fahr., and as at that heat steel retains only about thirty per cent. of its original strength, it is clear that an iron or steel vessel which was to hold the plastic metal could not resist the internal pressure necessary to cause the charge to flow through the small orifice of the die. Various grades of steel, as well as iron, wrought and cast, were tried; they were heated in coke fires, with gas, or by other, more or less suitable, means, but until Mr. Dick succeeded in building up a composite container, he was as far from the desired end as ever.

The invention of the composite container, however, practically solved the problem. This container is formed of concentric steel tubes, each separated from the other by a layer of dense non-conducting material, and built up in such a way that the telescoping action brought upon them during the operation by the friction of the metal against the inner walls, has simply the effect



DICK'S METAL SQUIRTING MACHINE

of, if possible, still further tightening them up.

It is evident that by the use of a container of such construction, both the first and the second difficulty were overcome; for not only are the outer tubes kept cold, and thus is all their strength retained, but the heat is also prevented from escaping and the interior of the container is, therefore, readily kept at the necessary working temperature. To further obviate the possible chilling of the charge, the dies are heated previous to each operation, and a loose block is placed in front of the ram, which is also heated up.

To prevent the back-flow of the metal past the ram, a disc or check-plate is used, fitting tightly in the container. This disc is placed between the plastic metal and the loose block just mentioned, and is of a metal more rigid and less plastic at the working temperature than the charge in the container.

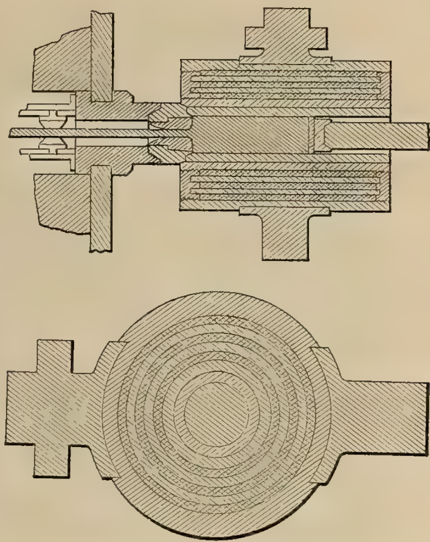
The press itself, as will be seen from the several illustrations in these pages, consists of a strong framework, at one end of which is the hydraulic cylinder whilst at the other end is a crosshead, having an opening through which the die-holder carriage with the die-holder and die pass. The first machine built, after an experimental press had proved the complete success of the invention, had a ram 16 inches in diameter, but at present machines of 20 inches are in use, capable of exerting a pressure of over 800 tons on the charge in the container, and still larger ones are being constructed.

The containers generally have a length of about 2 feet, and their interior diameter varies from 5 up to 10 inches, so that they will hold a charge of from about one to five cwts. and more. The die is placed in a die-holder which fits into a carriage attached to a frame on which are placed steel rollers. This frame, by means of a handle and a rack and pinion, can be moved forward and backward. The crosshead, through which the die-holder carriage passes, carries two small cylinders acting upon two jaws which can be opened and closed simultaneously and automati-

cally, and which serve for holding the die-holder in position during the pressing or squirting operation.

The container is mounted on trunnions, and can be turned from the horizontal or working position, into the vertical position in which it is charged. One end of the container, before charging, is temporarily closed by means of a plate and bolt. The molten metal is then poured into the container, or a heated billet may be placed inside instead of the molten metal, as described hereafter, and as soon as the metal is set and the check-disc placed upon it, the container is turned over and all is ready for the work.

The power necessary for working the press is supplied by either steam or power pumps, from 25 to 35 H. P. being sufficient. The working pressure of the pumps varies from about 25 cwts. up to 2 tons per square inch, according to the alloy or metal operated upon, and the section produced.



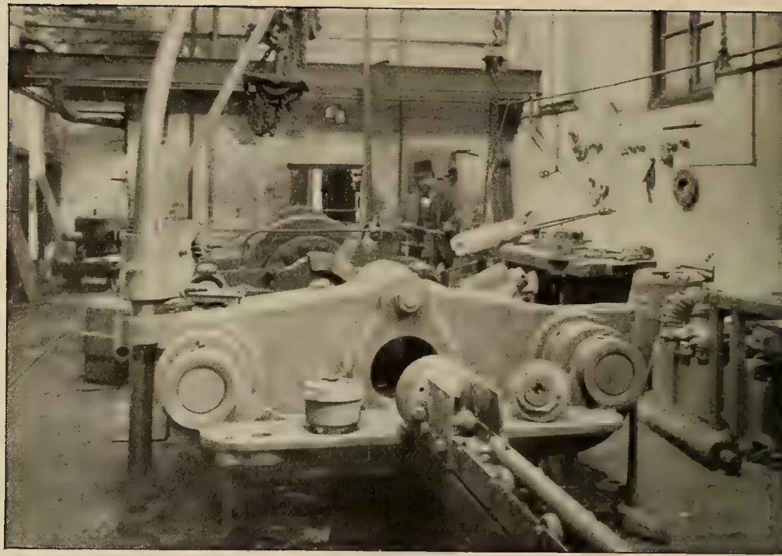
LONGITUDINAL AND CROSS SECTIONS OF THE CONTAINER.

SPECIMENS OF WORK DONE IN THE MACHINE.

The dies are made of a specially hard steel, which has one opening, or more, of the section which it is desired to give to the finished bar.

The edges of the openings of the dies are bevelled, in order to give free access to the squirted metal and avoid friction as much as possible. The die itself fits into a recessed holder which is placed in the carriage.

As stated previously, either molten metal or a heated billet can be used for



AN END VIEW OF A METAL SQUIRTING MACHINE.

charging the container. If the first-named is used, of course some time elapses, perhaps a minute and a half, until the metal is sufficiently set. When billets are used there is no such delay, but the billets must be heated up previously in a furnace specially constructed for the purpose. In practice, it is found very useful to combine the two methods, and in this case the billet is generally cast during the time the previous charge is operated upon, and as soon as the latter is squirted out, the billet is taken out of its mould, and placed into the container in a sufficiently hot state to require no further heating.

The total time required for squirting out the contents of a container naturally varies, not only according to the size of the latter, but also in accordance with the section produced, and the alloy used, but it may be taken to occupy from about two to four minutes. At this rate it will be seen that four or five tons of finished rods or other shapes can very easily be produced per machine per day.

As the molecules are compressed more intimately, the squirted metal becomes, by the operation to which it is subjected in the container, stronger and more homogeneous than it would be if rolled or drawn by the ordinary process-the increase in tenacity being ccnsider, able, with an equivalent increase in the elongation. For example, bars of Delta metal (No. 1 alloy) which, when rolled, had a tensile strength of 38 tons per square inch and 20 per cent. elongation, when squirted had a strength of 48 tons and 32½ per cent. elongation, as shown by tests made at Woolwich arsenal.

The great advantages of Mr. Dick's method of squirting may be summarised as follows:—Greater strength, solidity and homogeneousness of the produced metal or alloy; sections of any desired shape, even those which it is impossible to roll, produced easily and with perfect finish, by one simple operation—instead of as hitherto, the labourious and cumbersome process of passing them through a series of rolls and drawholes with intermediate annealing; great facility in changing the dies, and, generally, in manipulating the machine, for which only two men and a boy are required; and, finally, great saving in cost of production, as well as in first cost of installation.

A RECORD IN CHIMNEY RECONSTRUCTION.

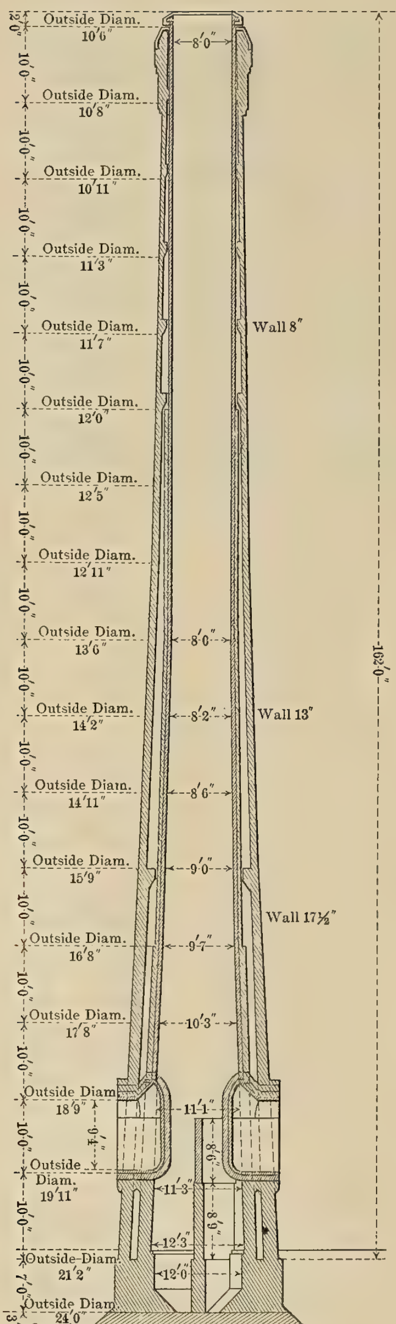
By E. D. Meier.

JUST south of the electric power-house of the Union Depot Railroad Company in St. Louis, Mo., U. S. A., stands a tall brick chimney, 162 feet high from the ground, with an internal clear diameter of 8 feet. This chimney has a history. It was originally built in 1890. The foundation of brick and concrete, placed on the red clay hard pan 10 feet below the surface, had been completed to the street level, and the contract called for the building of the entire stack, the outer shell 160 feet high, the core 162 feet high, with the caps in place, in 45 working days. This meant the laying of 273,000 bricks and the raising of the scaffolding and the steam hoist as the work progressed. It was actually finished in 43 working days. The illustration on the next page shows the elevation and section of the stack, taken from the working drawings.

The chimney had been in constant use since its completion in October, 1890, and was destroyed by a tornado which swept over St. Louis on May 27, 1896. There was too much to do on the following day, looking after the safety and comfort of friends who had suffered in the general devastation, to examine closely into the fall of the stack. But on the morning of the 29th the writer made a personal examination and also talked with eyewitnesses, and on the same day noted down his observations as follows:—

"On May 27, about 5 P. M., this smoke stack, which was 162 feet high from the ground, built in two shells, the outer shell of best red brick laid in mortar made half of Puzzolan cement and half of best Glencoe lime, fell in consequence of the tornado which visited the city. Mr. Roach, the secretary of the Union Depot R. R. Co., was standing at the south window of the office, about 300 feet from the stack, and saw it fall. He described it as rising with a twisting motion and falling all in a heap toward the north. When I saw the stack on the morning of the 28th, there were about 50 feet of it left standing, or more properly speaking, there were somewhat over 50 feet on the south side and about 40 feet on the north, and the fracture was irregular and looked more as though it had been twisted off than if it had fallen from the direct pressure of the wind.

"Most of the débris from the stack lay in a pile about the large engine, almost directly north of the original position of the stack. Another engine which was only 28 feet east of the centre line of the stack and therefore less than 18 feet from its eastern edge, was scarcely touched, and about as much of the brick work lay some 20 feet to the west of said centre line. The bulk of it had fallen within 60 feet to the north of the centre of the stack and very little of the débris had gone beyond the north wall of the building, only 96 feet from the centre of the stack. As the portion which broke off was from 110 to 120 feet long, it is evident that it



A VERTICAL SECTION OF THE CHIMNEY.

could not have fallen straight forward, since in that event a great quantity of the débris must have been thrown from 60 to 100 feet further.

There was very little of the fire-brick of the stack on the street. A few loose bricks had been thrown some distance into one of the neighbouring streets, but they were very few and far between. From a personal observation of the débris which I made this morning, May 29, I judge that most of it fell within 50 feet of its original position, and it lay in a sort of rough oval. This would bear out Mr. Roach's description, since if it had a twisting motion and was at the same time blown northward, the débris must assume approximately that shape.

"When I examined the ruins this morning, May 29, I found some of the fire-brick ouiside of the north wall of the building but was informed by the men who were clearing up that they had been thrown out yesterday afternoon and this morning. I am, therefore, of the opinion that Mr. Roach's description is substantially correct, and that the cause of the destruction of the stack is due more to the twisting motion of the tornado, possibly creating a partial vacuum in the centre, than to any direct overturning force of the wind. The copper cap from the top was found about 75 feet north of the centre of the stack."

A careful investigation of the force of the wind, made by Mr. Julius Baier, C. E., and published in Vol. 37, June, 1897, of the Transactions of the American Society of Civil Engineers, gives an elaborate calculation of the minimum force exerted by the wind during this tornado. This chimney happens to have shown the greatest resistance of any building examined by Mr. Baier and he figures out that the pressure must have been in excess of 85 to 91 pounds per square foot over an area at least 14 feet wide by 110 feet high, and that the total material moved was 321 tons.

On May 29 a design was completed for a steel stack to be erected on the stub end of the old brick stack, and as the local sheet iron shops were naturally

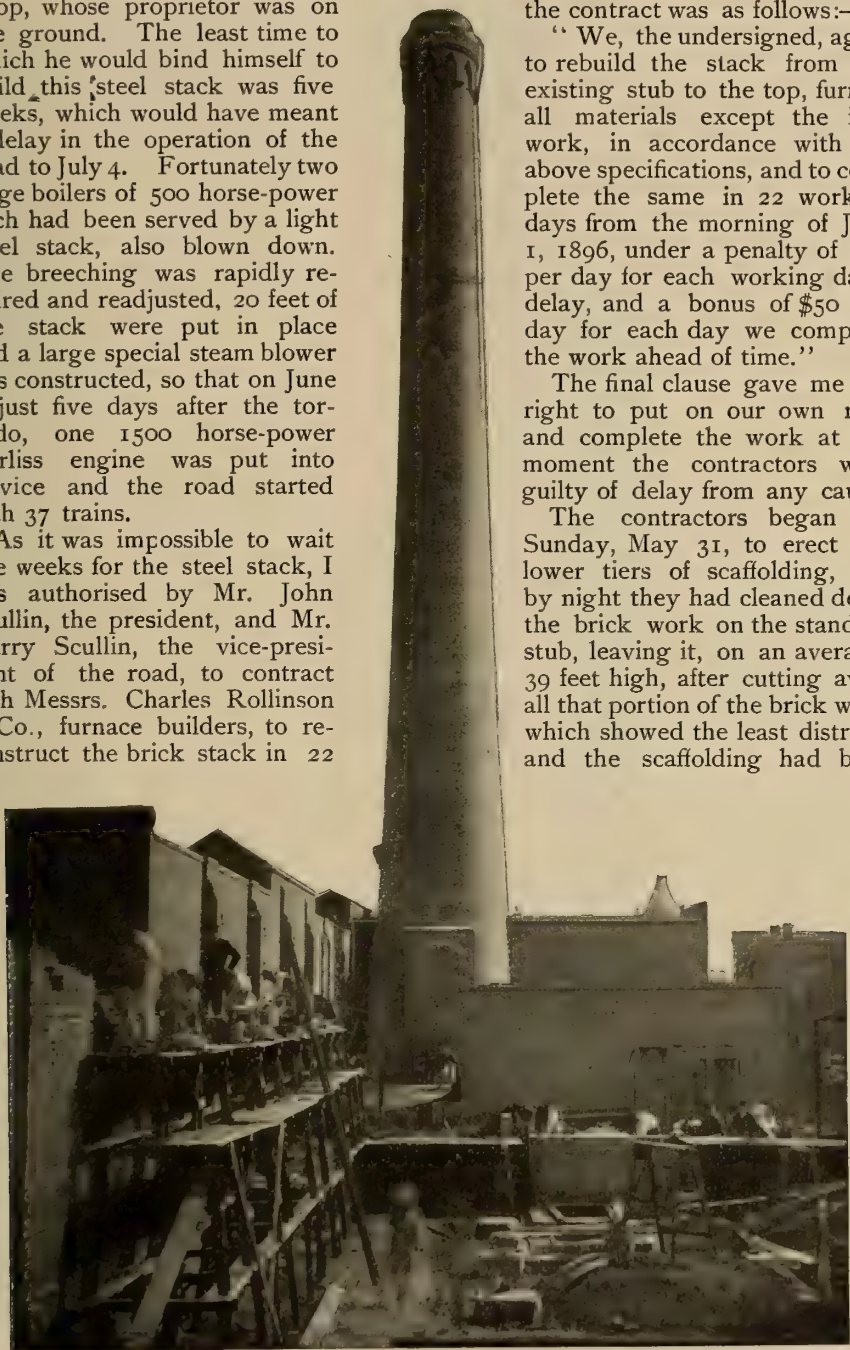
overcrowded with work, a time bid was asked from a Chicago shop, whose proprietor was on the ground. The least time to which he would bind himself to build this steel stack was five weeks, which would have meant a delay in the operation of the road to July 4. Fortunately two large boilers of 500 horse-power each had been served by a light steel stack, also blown down. The breeching was rapidly repaired and readjusted, 20 feet of the stack were put in place and a large special steam blower was constructed, so that on June 1, just five days after the tornado, one 1500 horse-power Corliss engine was put into service and the road started with 37 trains.

As it was impossible to wait five weeks for the steel stack, I was authorised by Mr. John Scullin, the president, and Mr. Harry Scullin, the vice-president of the road, to contract with Messrs. Charles Rollinson & Co., furnace builders, to reconstruct the brick stack in 22 working days from the morning of June 1. The first clause of the contract was as follows:—

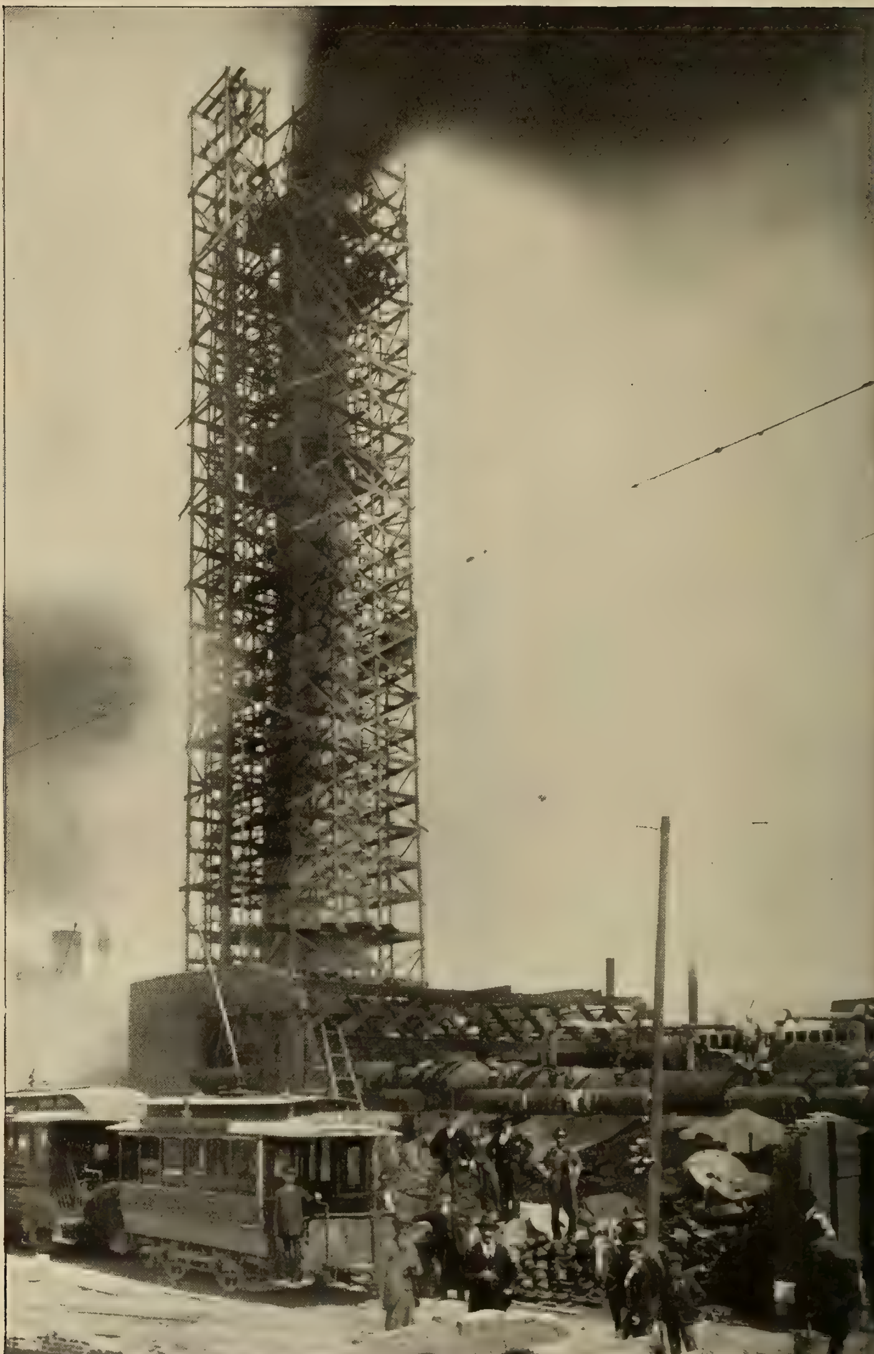
"We, the undersigned, agree to rebuild the stack from the existing stub to the top, furnish all materials except the iron work, in accordance with the above specifications, and to complete the same in 22 working days from the morning of June 1, 1896, under a penalty of $50 per day for each working day's delay, and a bonus of $50 per day for each day we complete the work ahead of time."

The final clause gave me the right to put on our own men and complete the work at any moment the contractors were guilty of delay from any cause.

The contractors began on Sunday, May 31, to erect the lower tiers of scaffolding, and by night they had cleaned down the brick work on the standing stub, leaving it, on an average, 39 feet high, after cutting away all that portion of the brick work which showed the least distress, and the scaffolding had been



CHIMNEY AT THE POWER HOUSE OF THE UNION DEPOT R. R. CO., ST. LOUIS, MO. DESIGNED BY E. D. MEIER. HEIGHT, 162 FEET. DIAMETER OF CORE, 8 FEET. MAXIMUM CAPACITY, 2000 H. P.



THE CHIMNEY DURING RECONSTRUCTION.

brought to a height of 40 feet. June 1 and 2 were consumed in placing the hoisting engines, running up the shaft and guides for the elevators, in mortar mixing, etc. At noon of June 3 everything was ready for work. At 10 A. M. three bricklayers began, and two more were put to work at 1 P. M., and by night they had brought the stack all around to a level of 44 feet.

On June 4 nine bricklayers brought it to a height of 59 feet. On June 5, nine bricklayers, in half a day, brought it to 67 feet, a violent rain storm preventing further work. On June 6 nine bricklayers had built it up to 82 feet.

At 8 A. M., June 7, fires were started under the boilers and the stack was put in service, and used 16 hours each day, the fires being drawn at 11 o'clock every night and cold air allowed to pass through the stack to enable the carpenters to work on the scaffolding. On the evening of June 7 the nine bricklayers had reached a height of 93 feet. On June 8, with eight bricklayers, a height of 104 feet was reached; on June 9, with eight bricklayers in the morning and nine in the afternoon, 112 feet 6 in.; on June 10, nine men, 126 feet; June 11, 142 feet; June 12, nine men, 156 feet; on June 13 the ornamental head was completed and the cast iron cap put on, making a height of 160 feet. On June 14, by 11 A. M., the core had been brought to a height of 162 feet, and the combination cast iron and copper cap was put in place.

The entire work was, therefore, done in one hour more than 11 working days so far as the provisions of the contract were concerned; but for a record in rapid work the men are entitled to a deduction of 6 hours for the half day lost on June 5 by extreme bad weather; making a further allowance that for 18 hours we worked only eight men, for three hours only three men, and for 6 hours only five men, it brings the exact working time down to 120⅓ hours for nine men. These men averaged, during 12 hours a day, 15,000 brick, so that each man handled 139 bricks per hour, or 2-$\frac{8}{10}$ bricks per minute.

This work had to be done from a frail scaffolding with just barely room enough to work. For the last 7 days the smoke interfered and these brave men had to work with shields over their eyes and wet sponges in their mouths. A light sheet-iron stack, 7 feet in diameter and 6 feet high, was always suspended in the core, and had to be raised every 3 feet. The carpenters who raised the scaffolding had to work at night by electric light, the bricklayers meanwhile sleeping in the cars which stood in the demolished car shed. At times the wind was so violent that loose boards on the top of the scaffolding blew off. The slight drizzling rain which frequently visited us during this period did not trouble the men or induce them to quit work. One of them said to me:—"What's the difference; if we go home we should have to sleep in wet beds because there is no roof on our house."

Mr. Charles Rollinson and his foreman, Mr. Fred Sellman, divided the work night and day in such a manner that one of them was always on the ground directing the actual work.

In just ten days and thirteen hours from the time of its destruction the chimney was again in use, and in 17 days and 17 hours it was entirely completed. The whole reconstruction, including the cleaning up of the débris, the erection of the scaffolding, engines, etc., occupied 13 days. After the stack was put in use, it became necessary to keep the outer shell cool and moist to enable the mortar to set. This was done by pouring water on it at intervals, and by opening sundry additional holes near the bottom, so that a strong draft of air was created between the core and the outer shell, which are a distance of about one foot apart at the bottom and approach each other to within two inches at the top.

The chimney has since been in continuous service for a period of over 18 months, and has passed through several severe storms in that time. But it is safe to say that neither the consulting engineer, the contractors, nor the workmen are hankering after a similar job.

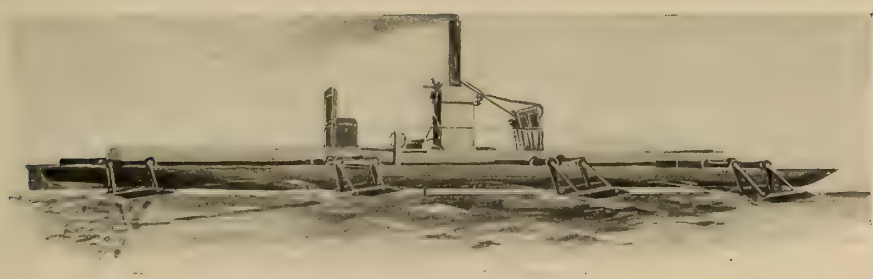
Current Topics.

It is not always possible to combine the useful with the beautiful. Progress must ever be associated more or less with some things that offend the sense of the artistic, but it is scarcely fair, because of this, to inseparably link the accomplishments of the engineer, as has been done so often, with the desecration of Nature's beauty and defacement of man's works of art. A smoky factory chimney is not a fit subject for admiration, but it may be an intermediary between some unlovely material product and a gem of human handiwork most pleasing to the eye. Considered by themselves, engineering structures have frequently been much abused by art critics simply because of their ignorance of the functions and purpose of the object criticised, and their inability to see, therefore, from lack of previous experience, that the general form and details, though differing from preconceived notions, were excellently fitted for their purpose. Sir Benjamin Baker, of Forth Bridge fame, dwelling on this topic some time ago in a presidential address before the Institution of Civil Engineers of Great Britain, stated that in the early days of bridge building, for example, art critics were familiar with arches and suspension bridges, and everything not of those types was unfamiliar and unlovely. They could see beauty and fitness in the masts and rigging of a ship, although they were nothing but mere struts and ties arranged for a special purpose, without any aim at artistic effect; but they could see none in a lattice girder, however well-proportioned, because of unfamiliarity and ignorance.

Engineers are weak enough occasionally to attempt to conciliate such critics, instead of gradually educating them by the construction of works scientifically and economically adapted to their purpose. We thus find so-called ornaments in the form of stars, scrolls, and finials plastered upon and about some of the earlier lattice bridges; we also see ancient marine engines with Gothic framework, constituting in effect an agglomeration of bent struts and crooked tie-rods in cast iron, with no bar in the direction of the stress; pumping and mill engines, with columns modelled after those of some Greek temple or Egyptian tomb, and early locomotives with a brazen American eagle perched on the steam dome, and appar-

ently shrieking with rage because he had alighted on so warm a spot. Commercial competition has aided good taste in doing away with all such monstrosities; and if engineers but honestly persist in designing works of a simple and scientific type, art critics will gradually become educated up to the necessary standard to enable them to detect the beauty of fitness in such works, as with longer experience they now see it in old timber-framed brick and tile cottages, fishing boats, windmills and waterwheels, and many other things whose designers gave small thought to anything but the purpose they had to fulfil and the nature of the materials they had to employ.

To make a boat which would raise itself out of the water as its speed increased and which would, therefore, merely glide on the surface, with a corresponding reduction of skin friction, has been the aim of many designers. No measurable success, however, has ever attended work on the problem. The general scheme of whatever gliding boats have been built in earlier years has been the use of inclined floats upon which the water would exercise an upward thrust, increasing as the speed increased, and it is this reactionary principle which has again been employed in the boat brought out last year by Count Lambert, of Versailles. The little sketch given on this page represents pretty fairly the manner of craft which he evolved, showing a boat made up of two hulls, connected by transverse metal tubes, with a central boiler and engine platform, — a kind of catamaran, in fact. Placed transversely under the hulls are four blades, fixed at a slight upward angle. The total surface of these blades amounts to about sixty square feet, while the weight of the boat is in the neighbourhood of 600 pounds. The propeller is 22 inches in diameter and has a pitch of 30 inches. As the boat moves forward, it gradually rises to the surface, and this, it is stated, is completely accomplished when the speed attained is about ten miles an hour. Beyond this speed the boat rises still higher, until only the extreme back edges of the blades touch the water. A number of trials have been made with the boat, which, by the way, was built in England, but at present not much appears to be known of their manner or their results, and what practical value may be attached to them yet remains to be seen.



A GLIDING BOAT.

It is assuredly not strange that business methods for the engineer should to-day be regarded as among his important equipments for successful work; the really strange thing is that for a long time their part has been ignored, belittled, perhaps, by some, and that the young man of the present time, turned out by even the best of engineering schools, is often without the knowledge of the very rudiments of business practice. In engineering, as in every other kind of business, competition and the reduced margin of profits have, of late years,

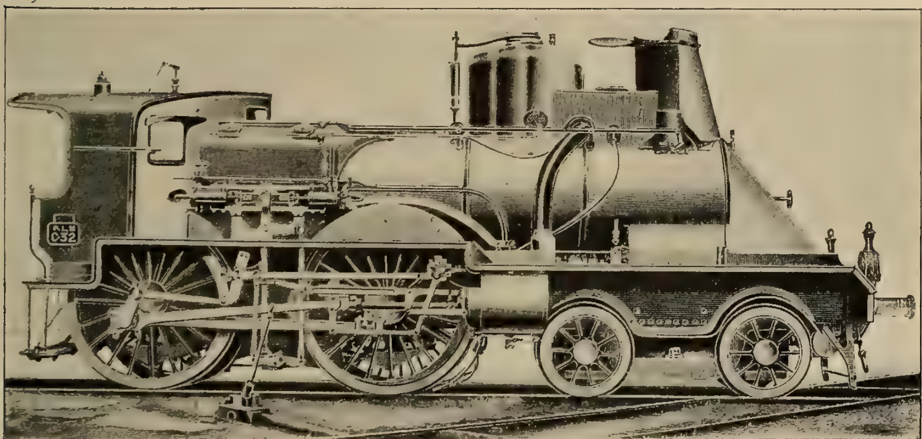
stimulated the introduction of economies all around; they have emphasised the importance of conducting business on business principles and of closely following systematised ways of doing things that formerly had a happy fashion of shaping themselves to the best ends. It is not the science of rational book-keeping alone that has forced itself into recognition, but all the details of shop and office management as well, of estimating costs, of making stock surveys, recording plant and buildings, of controlling correspondence, and a small host of other things. Engineering schools in many places have, however, gradually awakened to the fact that the engineer should have some commercial training, and courses of business lectures have been inaugurated in a number of them, representing thus the beginning of a branch of instruction of which the need has clearly become imperative. The successful engineer to-day is a good business manager, and if he be college-trained, he realises, more, perhaps, than any college professor can realise, that business lectures during his technical course would have saved him much hard work in later years, much disappointment, and certainly, in many cases, money. What business information he acquired was acquired by experience,—always a costly, though admittedly an efficient, teacher.

WHAT has called forth these remarks is a recently issued volume, entitled "The Commercial Organisation of Factories," prepared by Mr. J. Slater Lewis, the general manager of a large firm of engineers in Manchester, England, and published by Messrs. E. & F. N. Spon, of London and New York. There has always been a paucity of literature on this subject, and this particular volume, therefore, ought to find favour. Mr. Lewis says at the outset that his book is intended as a practical hand book for the use of manufacturers who wish to adopt modern methods of organisation, and it is, therefore, written throughout from the point of view of an organiser and manager. These few words broadly characterise the book. To review it even superficially would be entirely beyond the possibilities of the narrow space limits at command here, and we must content ourselves with drawing attention simply to its existence. The volume is an elaborate one. It comprises over 500 pages, and while it is not likely that all its suggestions and recommendations would be adopted in any one place, there can be little question that it presents food for a good deal of interesting and profitable study and reflection. The commercial side of engineering has rarely received too much attention, and it would be a matter for congratulation if literature similar in character were more generally available.

IT has been repeatedly mentioned of late as a noteworthy circumstance that in the operation of the electric third-rail system on the Nantasket Beach Railway, in Connecticut, no difficulties in running trains have come from flooding of the tracks. Water, under usual conditions, is a fairly good conductor of electricity, and short-circuiting, one might suppose, ought to result promptly when the tracks of such a railway are submerged. That this does not occur, however, was demonstrated years ago, in the earliest days of electric railroading, when Mr. Leo Daft ran his historical little line at Greenville, N. J. Mr. Daft had there laid down a short section of track, probably not more than an eighth of a mile long as it is now remembered, and ran back and forth on it a small motor car, purely for experimental purposes, and incidentally for the edification of privileged visitors to the grounds. At one point on the line there was a heavy depression, arranged intentionally, and the rails there were completely submerged; but notwithstanding this the little locomotive would spin along with undiminished energy, showing, as Mr. Daft intended, that the water over the rails had no injurious effect on the proper working of the line. In this instance, as in the case of the modern Nantasket Beach road, the simple

explanation of an apparent impossibility was that while the water was a conductor, yet the rails were much better conductors and the electric current preferably followed them as being the lines of least resistance. With at least one conduit road similar experiences have been recorded,—the line at Washington, D. C., where, some time last year, as the result of a heavy rainstorm, a stretch of track, about 150 feet long, became completely flooded, the water filling and overflowing the conduit. Although this state of affairs lasted for nearly two hours no short-circuiting took place and the cars were operated without a hitch.

UNUSUAL locomotive shapes seem to make their appearance epidemically, in bunches at one time, with intervals between during which designers appear to rest their tired fancies, in preparation, as it were, for new flights. Of these there were several during the year just passed, and one of the results was the new French express engine which is now running on the Paris-Lyons-Mediterranean Railway, and of which an illustration has been reproduced on this page from a recent issue of *The Engineer*, of London. Providing a locomotive with a wedge-shaped prow as a means of diminishing end resistance at very high speeds has been a favourite scheme with many who seem to forget that it is really the side-surface friction which counts and that their proposed air-plow arrangement simply adds to that, without affording more than the slightest measure of compensating advantage. The illustration of the French engine shows that something in the nature of such an air plow has been adopted in its make-up, and while in the published description of the design that we have seen no special mention is made of it, its appearance furnishes presumptive evidence that some good is expected to come from it. According to the data given in *The Engineer*, the locomotive is the first of forty, constructed to the designs of M. Ch. Baudry. It is compound, having two low-pressure and two high-pressure cylinders, the latter being outside the frames, and the steam, which is conducted to the chest by exterior tubes—one of which is seen—is distributed by Walschaert's valve gear. The low-pressure cylinders beneath the boilers are, for the sake of saving room and labour, provided with Gooch link motion. There are two entirely independent reversing gears. A large number of experiments has been made with several of these engines,



A NEW FRENCH COMPOUND EXPRESS LOCOMOTIVE.

but more with a view to testing the value of different points of cut off in the high or low-pressure cylinders than for the attainment of very high speeds, no very fast running having so far been attained with them.

An admirable contrast of the different methods of manufacturing iron and steel pursued in the United States and Great Britain was given in the July number of the United States Consular Reports. It is in the form of an article written originally for the London *Times*, which Mr. George F. Parker, the careful and painstaking United States Consul at Birmingham, vouches for as being the work of a specialist in this industry. The writer points out that one cause of the cheapness of American iron and steel is the gigantic scale on which the various plants are now built and operated. In illustration of this fact, he shows that each of the new Carnegie blast furnaces, at Duquesne, near Pittsburgh, can turn out 200,000 tons of pig iron per annum, whereas the average annual capacity of the British blast furnaces in operation in 1896 was only 23,682 tons each, from which it follows that forty blast furnaces of the new Carnegie type could replace the three hundred and sixty-two that now give a total output of pig iron in Great Britain. Similarly, the same writer says, there are now in the United States several rolling mills capable of producing 50,000 tons of finished steel rails a month, which is more than the total output of Great Britain for the same period, and probably three times as much as any one rolling mill in Great Britain can produce in a year. Moreover, the writer adds, the ores in America have to be carried from 600 to 800 miles to the blast furnaces, while the finished products have to be hauled 500 miles by rail to tidewater and carried 3200 miles by sea before they enter into competition with British-made steel, which in all cases is manufactured close to shipping ports. This brings him to contrast the cost of carriage by rail in Great Britain, where it averages from 1d. to 1½d. per ton-mile, with that of the United States, where it averages about one-seventh as much.

These examples bring out with great clearness the superiority in enterprise and audacity which the American has over the Briton. The American, speaking generally, manufactures his product ahead of demand, while the Briton waits for orders. The American who makes money uses his surplus capital to increase his output in order that, by manufacturing on the largest scale, he may decrease the cost per unit of product, while the Briton uses his surplus capital to buy lands and houses or to make secure investments by which he can leave his children independent of the fluctuations of his business. The American, in his fierce competition with his neighbours to command a market, tears down his plant at the end of a few years if he finds that he can substitute a new and improved one which will enable him to make his product more economically, while the Briton is disposed to let well enough alone.

In America, capital flows toward the successful man and he avails himself of it; in Great Britain, a man similarly situated is apt to consider that handling the capital of others is an added burden to life without any compensating advantages except the chance of making more money, of which he has already enough. The character of the American king of industry has been formed by the vastness of his country, its marvellous opportunities for development, its incomparable material progress in so short a span of time, its isolation from competitors, and, above all, its unbroken record of increasing wealth. For men trained under such auspices, no task is too difficult, no risk is too great, no amalgamation of interests is too large, while the British kings of industry, "cabined, cribbed, confined" on a small island, opposed on every side by hostile tariffs, hampered by the conditions of former successes achieved through caution, accustomed to work

on the orders of middlemen instead of seeking markets direct, have, in their turn, been moulded so that they have come to prefer security to enterprise, steady returns to enormous risks, personal supervision to corporate management of combined interests on a vast scale. Such is the contrast, though it is not altogether as one-sided as it seems. If the American watchword is "audacity," the British watchword is "stability." If the American is dependent on prosperous times to make a fortune, the Briton is equal to meeting prolonged bad times without losing one. The product of the velocity of the one and the mass of the other would be a momentum strong enough to transform the world.

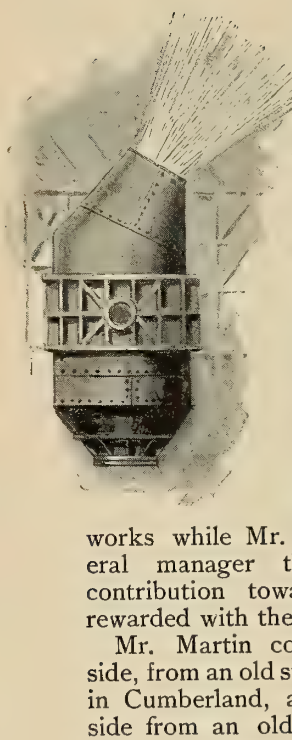
Apropos of magnets for lifting purposes it is interesting to note that some one has suggested their application to the raising of iron and steel vessels sunk in deep water,—too deep to admit of the employment of divers. One proposed scheme has for its object the raising of the ill-fated *Victoria*, of the British Navy, which now lies at the bottom of the Mediterranean, in 450 feet of water, off the harbour of Tripoli. The weight of the wreck in water is estimated at 7000 tons, and the suggested methods of raising it is as follows:—Powerful hydraulic rams and dynamo machines, and a series of heavy electro magnets are to be arranged on pontoons at the scene of the wreck. A magnet, lowered over the side and coming within reasonable distance of the sunken vessel, would be drawn towards the latter, and, on touching any iron or steel part of it, would immediately stick to it with a power of 100 tons. As each magnet made attachment, which would be indicated by means of an electric dial on the pontoon, a trial pull would be given to the rope to ascertain that a connection had been made to a firm part of the wreck. Should this not be the case the magnet would come off; its position would be then slightly moved and a fresh attachment made until a firm hold had been taken of the wreck. When all the magnets had been thus fixed, the wreck would be considered ready for raising. Each lifting rope would be attached to the lifting pontoon by means of a sheave on the head of a hydraulic lifting ram having a stroke of 12 feet, which would give an effective lift of 24 feet. Each hydraulic cylinder on the pontoon would be in connection with all the others, and a balancing accumulator would prevent any rope getting more than a normal strain of 100 tons. When the rams had made their full stroke the lifting ropes would all be simultaneously held in position by means of special hydraulic lifting blocks. The rams would then be lowered and another lift of 24 feet given to the wreck, and the operation would be repeated until the wreck would be raised sufficiently near to the surface to be towed to shallower water and there beached. However, all this is, at present, simply in the nature of a suggestion, more interesting probably than practically valuable, especially as the roughly estimated cost of its execution runs up close to the £100,000 mark.

It is an unfortunate fact that one of the main objects of the device known as the tension carriage in rope driving systems laid out on the continuous, or American, plan, namely, the equalising of the strains on all parts of the rope, is rarely attained to the fullest possible extent. Ropes often have been found to break long before their proper time, and nearly always, in such cases, because a few of them were doing more than the share of work intended for them, showing that something was wrong with the general layout. Mr. Spencer Miller, who, by the way, contributes to this number an article on American cableways, has laid the whole blame on the grooves of the larger rope sheave, which, he maintains, being the same as the grooves of the smaller sheave, do not allow the ropes to slip easily in them as they do in those of the smaller sheave with the smaller arc of contact. Widen the angle of the larger sheave grooves so that the resistance to slipping is equal in both

sheaves, let the rope adjust itself more readily to the strains by slipping momentarily and you will increase both the life of the rope and its driving power, sometimes by as much as 100 per cent. This, briefly, is his argument, and upon it Mr. Miller based, and received, a patent several years ago. What may not be inaptly termed the Miller system of rope-driving, therefore, provides for equal tension throughout the strands of a rope-drive by widening the groove angle of the larger pulley so that the resistance to slipping is equal in both pulleys. This does not lessen the power transmitted, as may be thought by some; but increases, doubles it, in fact, in some instances, as already mentioned, and all because of the increased average pull of the ropes.

EDWARD PRITCHARD MARTIN.

A Biographical Sketch.



IN metallurgical circles more particularly the name of Edward Pritchard Martin will always carry with it a reminder of the early days of one of the most noteworthy achievements in steel making, — the Thomas and Gilchrist dephosphorising process, which was worked out by the two inventors, Thomas and Gilchrist, at the Blaenavon Company's works while Mr. Martin was the general manager there, and for his contribution towards which he was rewarded with the Bessemer medal.

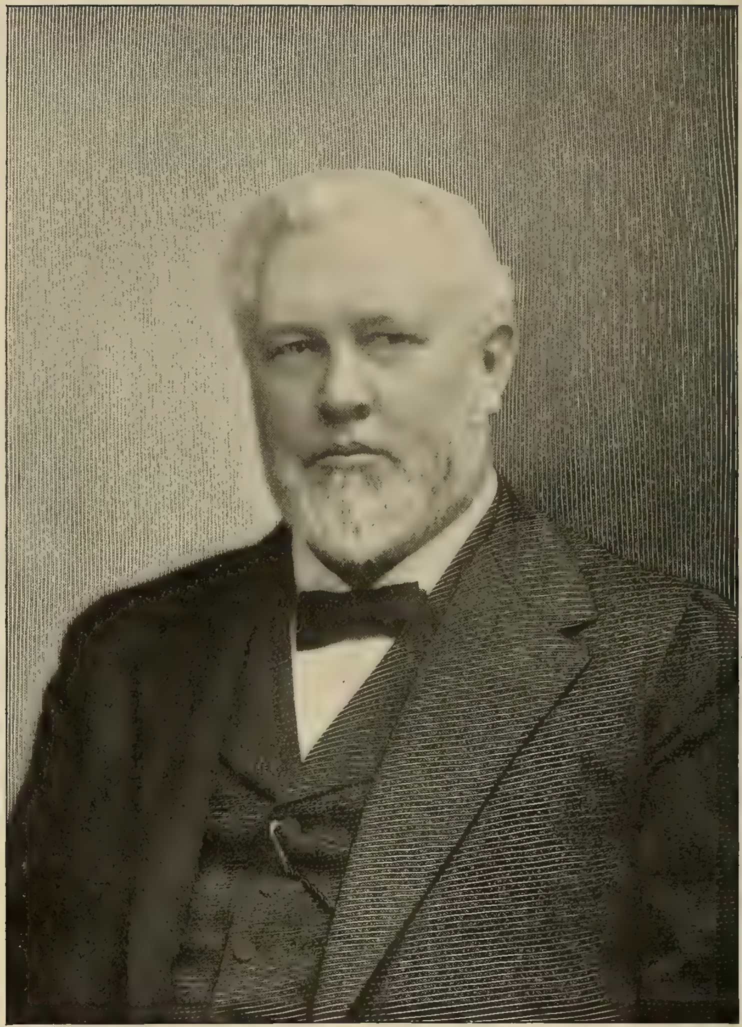
Mr. Martin comes, on his father's side, from an old stock of mining people in Cumberland, and on his mother's side from an old Breconshire family. He is the eldest son of the late Mr. George Martin, who was mining engineer for the Dowlais Iron Company for upwards of 58 years, and was born at Dowlais in 1844. He was privately educated in England and subsequently studied in Paris.

He was apprenticed to the Dowlais Iron Company in 1860, under the late Mr. Menelaus and the late Mr. Edward Williams, both past presidents of the British Iron and Steel Institute, and accompanied Mr. Williams to London to assist him in the management of Guest & Co., the London office of the Dowlais Iron Company. In 1869 he was appointed deputy general manager of the Dowlais Iron Works under the late Mr. Menelaus.

In 1874 was appointed general manager of the Blaenavon Co.'s works, where he erected the Bessemer steel works and where, as first mentioned, he identified himself with the historic work of Messrs. Thomas and Gilchrist.

In 1882 he was appointed general manager of the Dowlais Iron Company under the trusteeship of Mr. Clark, thus following in the footsteps of his late friend and chief, Mr. Menelaus, and this post he still holds.

He is a past president of the South Wales Institute of Engineers, vice president of the Institution of Mechanical Engineers, a member of the Institution of Civil Engineers, a past president of the Monmouthshire and South Wales Coal Owners' Association and a member of its Sliding Scale Committee. He is now president of the Iron and Steel Institute.



PHOTOGRAPH BY ELLIOTT & FRY, LONDON.

Charles W. Hunt.

PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

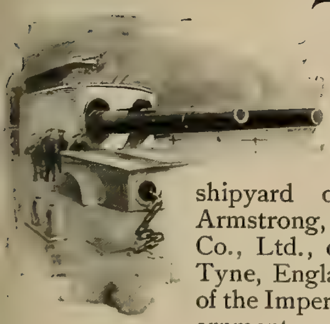
CASSIER'S MAGAZINE.

VOL. XIII. FEBRUARY, 1898. No. 4

THE JAPANESE BATTLESHIP "YASHIMA."

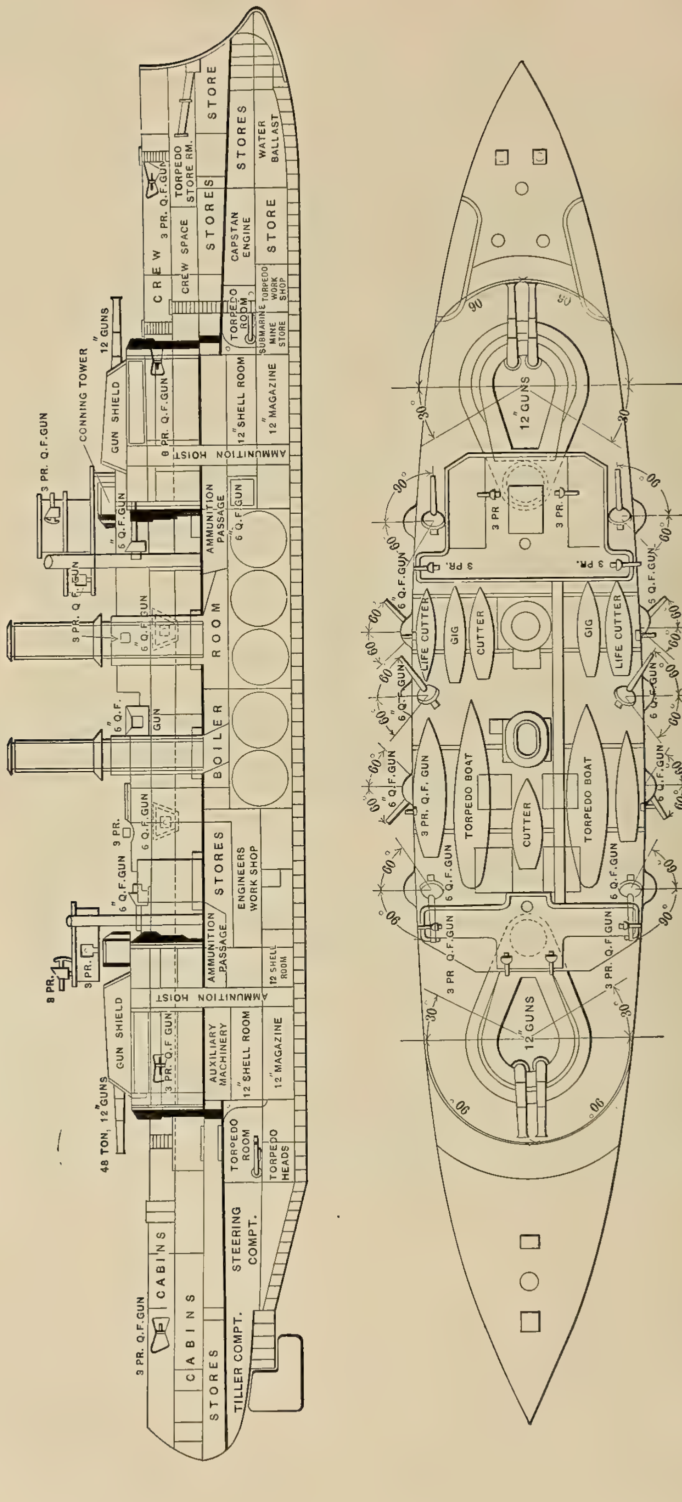
THE FASTEST ARMOURCLAD IN THE WORLD.

By E. H. T. D'Eyncourt, M. I. N. A.



THE first-class battleship *Yashima* has only recently been completed at the Elswick shipyard of Sir W. G. Armstrong, Whitworth & Co., Ltd., of Newcastle-on-Tyne, England, to the order of the Imperial Japanese Government. She has been built from designs prepared by Mr. Philip Watts, the director of Elswick Shipyard, and her recent success adds another to the now lengthy list of his triumphs as a naval architect. The *Yashima* is, however, in some sense, a new departure, for though, of course, Mr. Watts acquired great experience in the design of all classes of warships during his career at the British Admiralty, yet hitherto the most famous vessels turned out under his direction by the Armstrong firm have been of the various so-called "cruiser" types, and it is hardly necessary to recall the names of such vessels as the Italian cruiser *Piemonte*, the Argentine *25 de Mayo*, the Japanese *Yoshino* and the Chilean armoured cruiser *Esmeralda* and many others to bear testimony to the great reputation of the firm in the design and construction of this class of vessel. It has, however, been reserved for the *Yashima*, the largest vessel built at Elswick, to prove that the wide experience gained with cruisers of all types can be applied with the greatest advantage to the construction of the largest armoured battleships.

It was towards the latter end of the year 1893 when the Japanese Government asked several firms to tender for the construction of two first-class battleships, various conditions as to speed, armament, and other features, being laid down, to which the firms tendering had to conform, the design being left to the judgment of the builders, together with complete responsibility for the success of the vessels. The result of this enquiry was that Messrs. Armstrong were entrusted with the design and construction of one vessel, while the tender of the Thames Ironworks and Shipbuilding Company, Ltd., of London, was accepted for the other. The principal features in the design of the *Yashima* are as given below, and the profile, in section, and plan of the weather decks,



SECTIONAL ELEVATION AND DECK PLAN OF THE "YASHIMA,"

the opposite page, will be of assistance in tracing the various characteristics of the vessel.

The extreme length, from the point of the powerful under-water ram to the after end of the counter, is 412 feet, the length between perpendiculars from the cut water forward to the axis of the rudder being 40 feet less, namely, 372 feet. The extreme breadth of the ship is 73 feet 6 inches, and the normal draft of water is 26 feet 3 inches, which might be increased by about one foot with the coal bunkers quite full and an extra supply of provisions, water, and other stores.

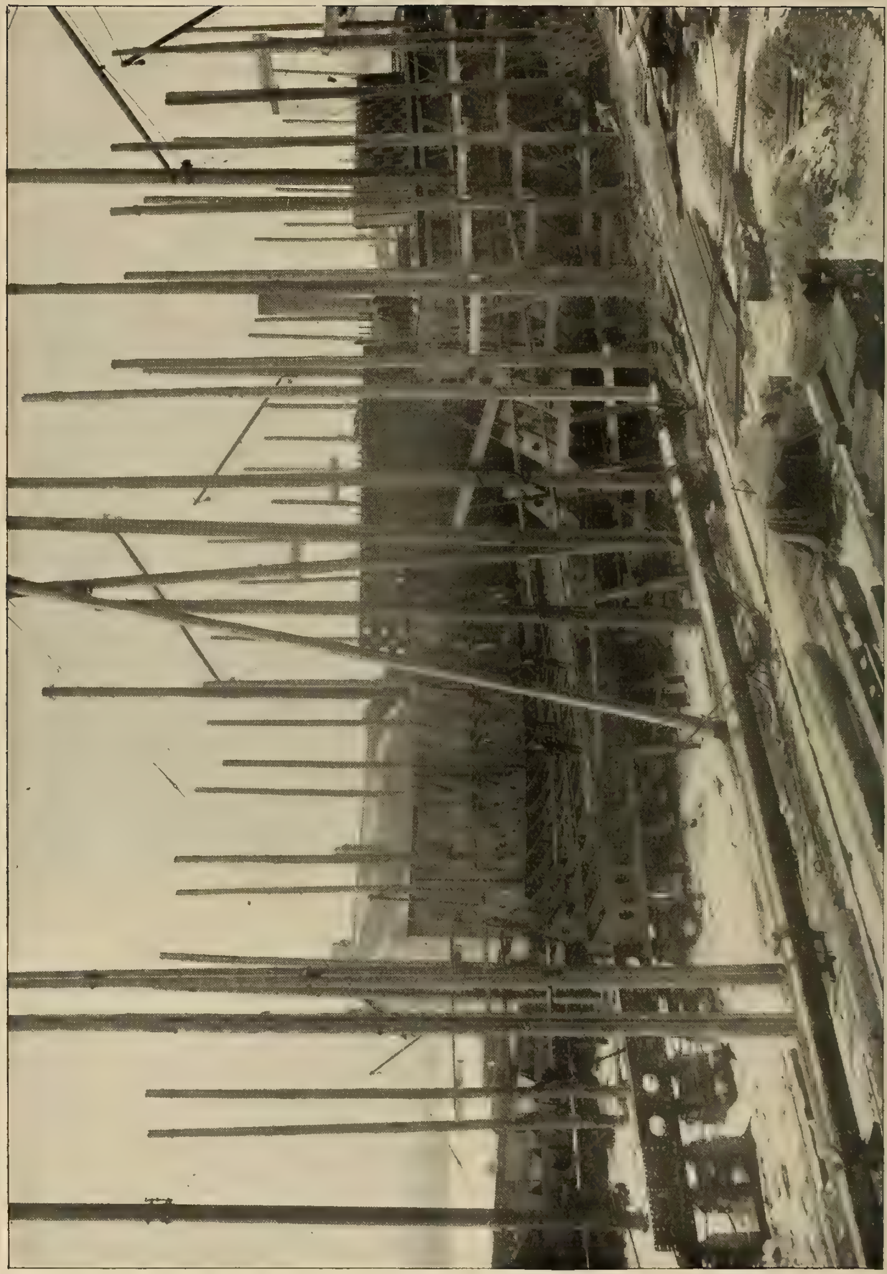
A GENERAL VIEW OF THE "YASHIMA" AFTER HER SPEED TRIALS.

On the 26 feet 3 inches mean draft the displacement is 12,320 tons, and this may be called the *Yashima's* "fighting weight." On this displacement she carries a complete supply of ammunition and stores, together with provisions and fresh water sufficient for a lengthy cruise, and 700 tons of coal out of a total of 1200, which is the full capacity of her bunkers.

Her armament and that of the *Fuji*, —the sister vessel built at the Thames Iron Works,—have both been supplied by Messrs. Armstrong, and each vessel carries four 12-inch, 49-ton guns, mounted in pairs in two barbettes, one at each end of the vessel, the guns themselves being protected by heavy revolving gun houses made of 6-inch armour. The axes of these guns are 25 feet 6 inches above water in the case of the forward pair, and 25 feet for the after pair.

Next in importance to the 12-inch guns are ten 6-inch quick-firing guns, six mounted on the upper deck and protected by heavy shields revolving with the guns, while the remaining four guns are placed in casemates or fixed armoured stations. These casemates have fronts of 6-inch armour and backs made of 2-inch steel, each gun being thus completely isolated and protected from the results of shell bursting 'tween decks or from fire.

Armoured trunks for the supply of ammunition are carried direct up from the ammunition passages below into each of the casemates, as well as to all the upper-deck guns, so that the gun-



A GENERAL VIEW, TWO MONTHS AFTER LAYING THE KEEL.

ners in charge of each gun can work without exposing themselves, receiving orders from the commander in the conning tower or elsewhere through voice pipes in direct communication with each gun.

The minor armament consists of twenty 3-pounder quick-firing guns, placed in convenient positions on the bulwarks and elsewhere, and there are four 2½-pounders carried in the fighting tops of the two masts; lastly, there are five torpedo tubes, four of which discharge below water and the fifth is fixed above water in the stem.

There is an ample supply of ammunition of every kind in magazines at each end of the ship, so that it one magazine were put out of action by flooding, or from any other cause, all the guns could still be supplied from the other. All the latest Elswick devices for quickly conveying ammunition from the magazines and shell rooms to the guns have been provided. The 12-inch ammunition is taken direct up from the handing rooms by two alternative routes into each barbette, whilst the 6-inch is first conveyed into one of the ammunition passages, two of which connect the magazines at either end of the ship, and from there it is sent direct up to each gun as required.

A DECK VIEW, LOOKING AFT, ONE YEAR AFTER WORK COMMENCED.

The defensive qualities of the *Yashima* are of no less importance than her offensive powers, and in this particular she compares most favourably with any contemporary vessel of her displacement. All her main armour is of steel, treated by the Harvey process, and has been supplied by Messrs. Cammell & Co., Ltd., of Sheffield. Mention has already

A VIEW OF THE AFTER END, TWO MONTHS AFTER BEGINNING WORK.

been made of the methods adopted for the protection of the guns themselves; the barbettes which protect the bases and machinery of the big guns are carried from about four feet above the upper deck, right down to the protective deck, and are of 14-inch armour on the upper portions, reduced to 9 inches on the part below the main deck.

Between the main and protective decks 4-inch armour is carried right around the ship's side as far as the barbettes, and behind this 4-inch armour coal bunkers are arranged, so that even if a projectile pierced the armour it would generally have to pass through about 12 feet of coal belt before any real damage was done.

The protective deck is of 2½-inch steel plating from end to end. Over the midship part, as far as the main transverse armour bulkheads, this deck is 3 feet above water and is carried on the top of the water-line belt armour. Outside the bulkheads it drops down below the water level and is slightly curved; at the fore end it is rigidly connected to the casting of the ram which it thus helps materially to strengthen, and aft it affords complete protection to the rudder head and steering gear.

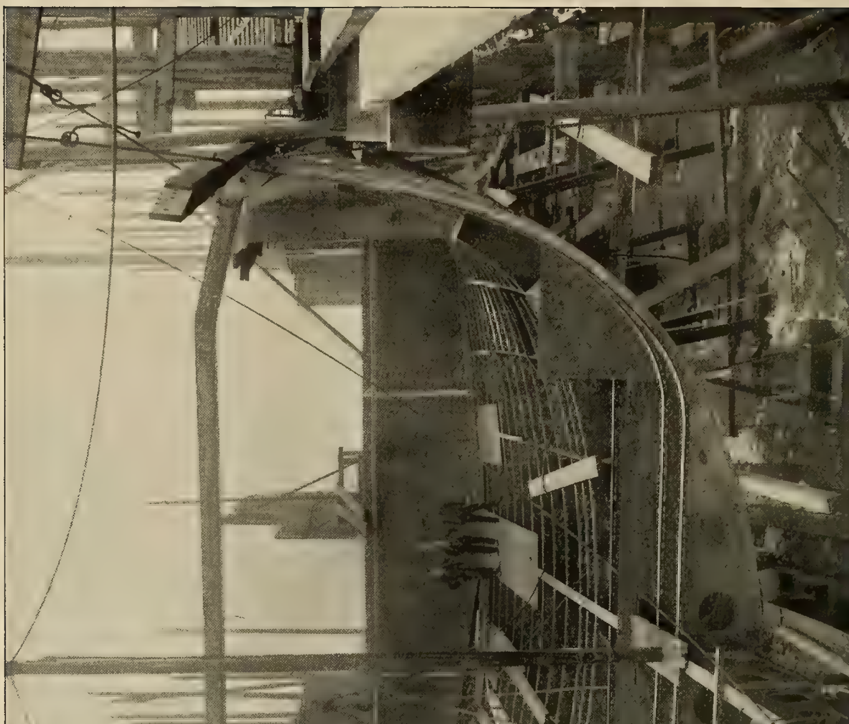
The main armour belt extends over a length of nearly two-thirds of the vessel and is terminated by transverse bulkheads carried square across the ship at each end. The fore-end bulkhead has a thickness of 14 inches; the after one is 12 inches thick. The belt itself is 18 inches thick over the length of the space occupied by the engines and boilers, and beyond this it is reduced to 16 inches and finally to 14 inches where it joins the armour bulkheads. In depth it extends from the under side of the protective deck, as described above, to five feet below the normal water line, thus having a total depth of eight feet. The extremely hard face of this armour belt, combined with its great thickness, should make it impervious to the attacks of any guns now being manufactured; in fact, the writer believes that no thicker armour treated by the Harvey process has ever been used upon any ship of war.

The *Yashima* has a conning tower 9 feet in diameter, with sides of 14-inch armour, and it stands upon the after end of the forward barbette. The rods and tubes which regulate the steering gear, telegraphs, etc., are thus protected by the barbette armour till they are carried to a position of absolute security below the protective deck. The conning tower is fitted with every means for working and fighting the ship from within its shelter, the commander being able to control the steering by means of a telemotor, besides being in direct communication with the engine room staff, with all the gun stations, and, in fact, with every position of importance throughout the ship.

The defence of the *Yashima* is completed by torpedo netting, which has been supplied by Messrs. Bullivant & Co., Limited, of London. When not in use, this netting is stowed on a grating along the ship's side, but when required, it can be rapidly lowered into position with the help of the booms which are shown on some of the illustrations.

The main propelling machinery of the *Yashima* has been designed and fitted by Messrs. Humphrys, Tennant & Co., Ltd., of Deptford, who also supplied precisely similar machinery to the sister ship *Fuji*. The *Yashima* has, of course, twin screws, the engines being placed in two separate watertight compartments. They are of the three-stage, compound, vertical, direct-acting type, and have cylinders 40 inches, 59 inches and 88 inches in diameter, with a stroke of 3 feet 9 inches. The specified indicated horsepower was 10,000 with natural draft and open stokeholds, and 13,500 with forced draft.

The boilers are of the ordinary single-ended return-tube type, ten in number, placed in four separate watertight compartments, each boiler having four furnaces, and each pair of furnaces having a combustion chamber in common. There are eight fans below the protective deck for keeping up the air pressure in the stokeholds when working under forced draft. An auxiliary boiler is fitted on the lower deck for working the nu-



THE FORE END, TWO MONTHS AFTER LAYING THE KEEL.

merous small engines throughout the ship.

The speeds guaranteed by the contract and corresponding to the horsepower given above were 16¾ knots with natural, and 18¼ knots with forced draft. In the case of the *Yashima* these were largely exceeded on the trials, of which an account is given further on.

The *Yashima* is provided with very powerful pumps, the total pumping capacity being equal to the discharge of about 2000 tons of water per hour, so that a very considerable inflow of water from any damage could be kept well under, and the subdivision of the ship throughout into 181 separate watertight compartments reduces the danger of sinking to a minimum; the vessel would remain afloat and retain her stability if both ends outside the armour belt were completely riddled with shot and shell and open to the sea.

The general equipment of the vessel is most complete; she is specially well provided with anchors, cables and gear in connection. The four bower anchors each weigh 5½ tons, and in addition she has four smaller anchors. This is an exceedingly powerful anchor equipment, but a very necessary feature for a vessel which will have to withstand the full force of the typhoons in the Pacific.

She carries twelve boats in all, including a steam pinnace, and two torpedo vedette boats, 60 feet long, for which a powerful steel derrick and hoisting machinery are provided. This derrick is attached to the mainmast, which is specially supported to withstand the consequent strains brought upon it; and there is a smaller derrick on the foremast, both being plainly visible on some of the accompanying illustrations.

The accommodation provided for the officers and crew is well arranged, all the living quarters being fitted up in the most comfortable, not to say luxurious, style. The total complement of officers and men is 600, including an admiral and 36 officers. The ventilation and lighting of the ship throughout are excellent. Besides five powerful search lights, about 600 incandescent electric lamps have been used for lighting purposes.

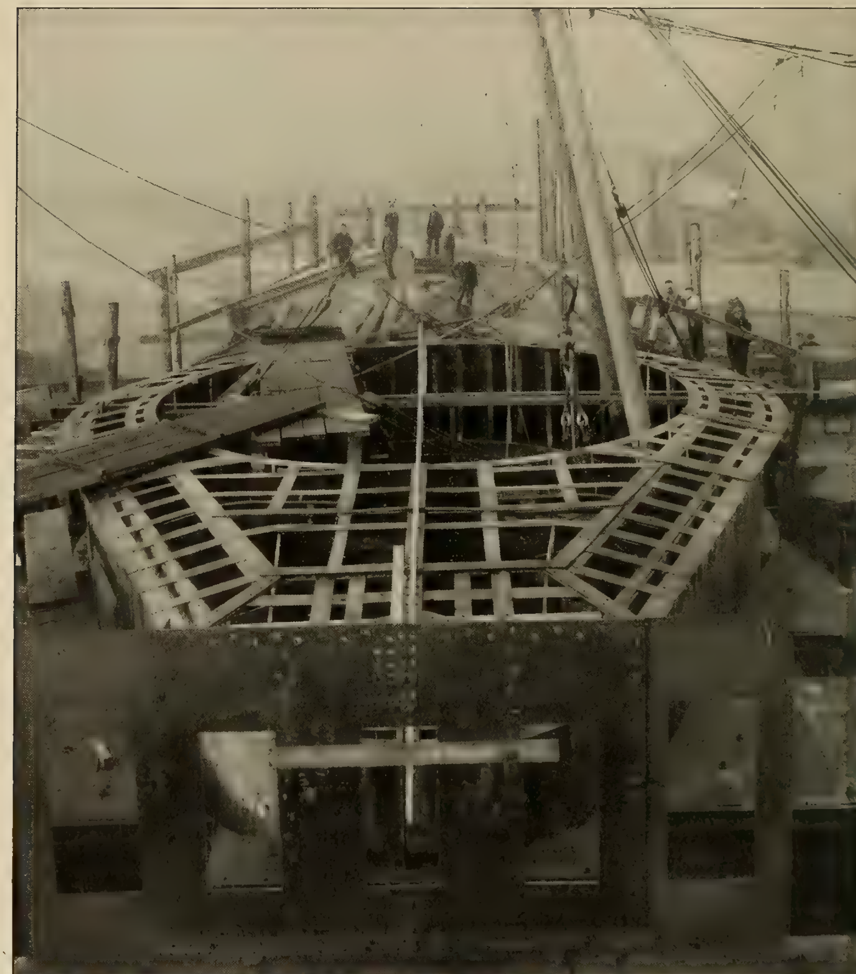
The actual building of the *Yashima* was begun at the close of 1894, the first keel plate being actually laid on December 6 of that year. The original date given for the completion was in 1898, but the Japanese Government asked for quicker delivery and it was decided to complete the ship in 2½ years from the commencement,—no easy task in a vessel of this size. In the early part of 1895 the progress of the building was greatly retarded by the very severe frost, which, it will be remembered, was one of the longest and most severe winters of recent years, completely stopping all outside work for some weeks in the shipbuilding yards in the north of England. Good progress was, however, made during the rest of the year 1895, as shown by the photographs taken during the construction of the vessel, of which reproductions are given in these pages.

The illustration on page 278 gives a general view of the vessel two months after the keel was laid and shows the system of construction; some of the inner bottom plates are in position, most of the flat and vertical keel plates are laid, and the framing is rapidly growing. The severity of the winter may be judged by the blocks of ice left by the river as the tide receded.

The photographs from which the illustration on pages 280 and 282 were prepared were taken at the same time as the one just referred to. The former shows a nearer view of the vessel taken from the after end. The method of building the cellular double bottom is clearly seen, and also the shelf and framing for supporting the armour. Some of the plates forming the inner structure behind the armour are in position, with holes in them through which the armour bolts are to be screwed up. This view gives a good idea of the great breadth of the vessel, and the shoring necessary to support the structure during building operations.

The view on page 282, taken from the fore end, illustrates the construction of the framing outside the limits of the

double bottom; some of the beams for supporting the protective deck have been erected and also part of the forward boiler room transverse bulkhead. The three figures in this photo are Mr. Carter, the yard manager; Lieutenant and the wood backing ready to receive the rest of the plates. One of the barbette armour plates has just been erected, and the framing and plating of the ship's side have been left out in this region to admit of more



A DECK VIEW, LOOKING FORWARD, ONE YEAR AFTER COMMENCING WORK.

Mera, of the Japanese Navy, who supervised the work, and Mr. Piddington, the under manager, standing in the order named.

The illustration on page 286, representing the vessel after 13 months' building, shows some of the armour belt plates at the fore end in position readily shipping the barbette armour. The average weight of some 40 plates composing the main belt, exceeds 26 tons each, and some of the plates approach 30 tons, so that very strong tackle and the greatest care had to be employed in erecting them. These plates were finally secured in position by

LAUNCHING THE GREAT SHIP.

bolts over 4 inches in diameter, about one bolt being allowed to seven square feet of surface of the armour.

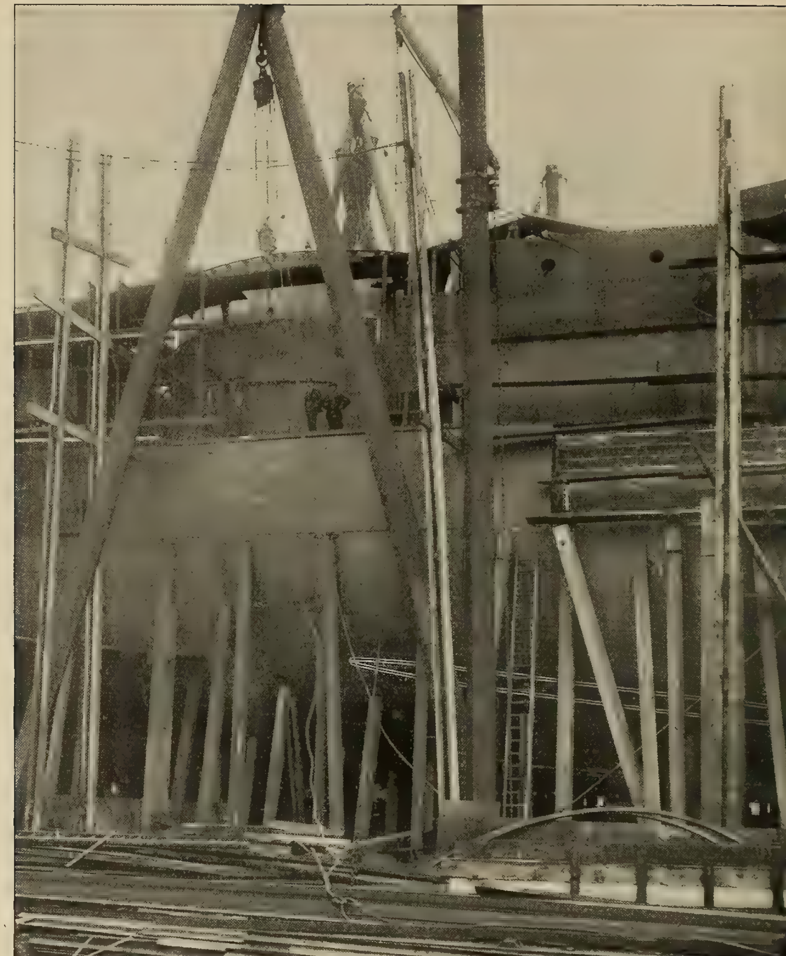
In this illustration four white lines can be seen low down on the shell plating; these mark the position in which the bilge keel is to be fixed on this side of the vessel, and there is, of course, a similar bilge keel on the other side. These are V-shaped in section, with a depth of 30 inches, and are 180 feet long. They are fitted in all the latest armourclads in the British Navy and most other navies, as they have been found most effective in checking excessive rolling in a sea-way.

The illustrations on pages 279 and 284 are views of the after and forward ends of the upper deck, taken a year after the keel was laid. One of the barbettes is shown in each view, and the wooden moulds, from which the glacis plates which cover in the top of the barbettes are to be made, can be clearly distinguished.

The launch of the *Yashima* took place on February 28, 1896, one year and two months after the keel had been laid. The illustration on this page shows the vessel just taking water. The cradle and launching ways were of a most massive and substantial character, as was necessary when it is considered that the vessel at the time of her launch had a weight of about 6500 tons of material worked into her, and that this enormous structure slid down the ways at a maximum speed of over 18 feet per second, or about 12 miles an hour, the declivity down which she glided being one of ¾ of an inch in one foot.

A strain of over 2 tons per foot came upon the ways, and 200 tons on the dog-shores which kept the vessel from moving up to the last moment before launching. Heavy drags were utilised to prevent the ship from running right across the river, and in the illustration the chain cables can be seen just tightening up on some of these drags, which finally brought her to rest in a comparatively short space.

The ceremony of launching and naming the vessel was performed by Madame Kato, wife of His Excellency M.



THE FORE END, AFTER THIRTEEN MONTHS' WORK.

Kato, the present Japanese Minister at the Court of St. James; and a very large company of Japanese and English ladies and gentlemen were present on the occasion. Lord Armstrong proposed success to the new battleship, and in reply M. Kato said that the arrival of the *Fuji* and *Yashima* in Japanese waters would mark an epoch in the history of the Japanese Navy.

After the launch the work of completing the vessel for sea and getting the machinery and armament on board was rapidly proceeded with, and though by the original tender the ship was to be completed by 1898, at the request of the Japanese Government the work was pushed rapidly forward so that the vessel was practically finished by June of last year, and on the 17th of that month she left Elswick Shipyard and was taken down through the high and low-level bridges as far as Newcastle Quayside.

The illustration on the opposite page shows the *Yashima* passing through the bridges, and as she is the broadest and deepest vessel that has ever done this (her beam being 3 feet 6 inches greater than that of the ill-fated *Victoria*), it may well be imagined that the utmost care had to be exercised in taking her through. An unusually high tide had

to be chosen and most careful soundings made beforehand, and the vessel had to be listed over 5° to port so that her starboard bilge might clear the foundations of the high-level bridge. Her bilge keels actually passed within a few inches of the masonry. This list can easily be detected in the illustration, which gives an excellent idea of the whole scene, with the crowds on Stephenson's high-level bridge, and with the low-level swing bridge (another creation of Armstrong's firm), just behind the great ship.

Immediately after passing the bridges she was moored for two days alongside the Newcastle quay, where, by the very kind permission of Captain Arima and the other Japanese officers on board, she was shown to hundreds of visitors, the proceeds of the exhibition going in aid of a local charity. The Japanese crew who had come from Japan to take the vessel home, had already been living on board for some time, and the public were thus enabled not only to see the internal fittings and arrangements of the vessel, but also to gain some insight into life on board a Japanese warship.

On leaving Newcastle quayside she subsequently steamed down to moorings on a lower reach of the Tyne, where her masts were finished, these being much too high to come under the bridge, and she was otherwise made ready for trial, taking in coal, water, ammunition, and other supplies.

The speed trials of the vessel occupied two days,—July 13 and July 14. The first day was devoted to the forced-draft trial, which was of four hours' duration. The mean speed attained during the trial was 19.227 knots, while the mean of four runs, taken over the Admiralty measured mile, was 19.46 knots, or more than a knot in excess of the guaranteed speed of 18¼. The engines developed just over 14,000 indicated horse-power, which was kept up over

THE "YASHIMA" PASSING THROUGH THE HIGH AND LOW-LEVEL BRIDGES AT NEWCASTLE

TRYING THE ANCHORS OF THE "YASHIMA."

the whole four hours without intermission, the pressure of steam being well maintained. The pressure of air in the stokeholds never exceeded that due to a head of 1½ inches of water.

The speed of nearly 19½ knots establishes the *Yashima* as the fastest armourclad in the world, and when it is considered that only a few years ago this was the utmost that cruisers, constructed specially for speed, could attain, it is a distinction of which the Japanese may well be proud.

Notwithstanding the severe test of the forced-draft trial, everything had worked so well and smoothly, that it was decided to make the trial with natural draft and open stokeholds on the day following. The vessel anchored off the Tyne for the night, everybody sleeping on board, which enabled an early start to be made with the 6 hours' continuous steaming at full speed.

The mean speed attained during this period was 17.26 knots, while the mean of four runs over the measured mile gave 17.73 knots, and this speed was maintained over a considerable time, and might have been kept up over the whole six hours if it had been considered desirable to do so. The mean power developed on this trial was 9570 I. H. P., which was maintained over the whole six hours.

The weather conditions on both days were favourable, the only point which gave the contractors cause for anxiety as to the results being that the great Engineers' Strike had begun, and Messrs. Humphrys, Tennant & Co. were thus deprived of nearly all their most experienced hands and had to do the work with men comparatively new to the job. They may therefore be most justly congratulated on having brought to such a successful issue so important a series of trials without the slightest hitch. It is needless to say that the splendid results obtained gave the utmost satisfaction to the Japanese officers on board, and to all concerned. On both trials the vessel was at her normal draft of 26 feet 3 inches with all weights on board.

After the completion of the six hours' natural-draft trial, the vessel was still kept going at full speed in order to test the steering gear and to measure the diameter of the circle made by the ship in turning.

Mr. Watts has always attached the greatest importance to good manœuvring qualities in the warships he has designed, and though it has not been previously fitted in any vessel so large as the *Yashima*, he decided to adopt in her case the form of balanced rudder which has been used in most of the Elswick cruisers with such conspicuous success. This rudder, combined with the shape of the lines aft (the keel or so-called dead wood being cut away towards the stern post, as may be seen in the sketch plan of profile on page 276), has without doubt given the *Yashima* manœuvring powers of the exceptional character which she certainly possesses. The trials which were made proved that she could make a circle not exceeding 1½ times her own length with both propellers going ahead, the time of turning through 180°, or reversing her direction, being 1 minute and 26 seconds.

The steering gear, which was supplied by Messrs. Harfield, worked splendidly, the rudder being put from hard over on one side to hard over on the other in 16 seconds with the help of the steam gear. Hand gear is also provided, and it was found possible to change from hand to steam and *vice versa* with great rapidity,—a point of the utmost importance in case of a breakdown.

Two illustrations are given of the vessel being steered round with the rudder nearly hard over. In the one on page 291 she is coming head on with the helm a-starboard, as can be seen by the helm signals attached to the yardarm, the ball being up and flag down. The one on page 290 gives a stern view with the helm aport, the flag up and ball down. In this view the wake of the vessel, streaming away from the stern almost at right angles to the line of keel, shows what a remarkably small circle the vessel was making.

All that remained now to be done be-

fore the *Yashima* left for Japan, was to carry out the gun firing and torpedo discharging trials on board. The *Fuji* had already been tested in these respects with most satisfactory results, so that the armament contractors had little to fear as to the successful completion of the trials with the second ship. A number of rounds were fired from the large and small guns, so as thoroughly to test the strength of the ship's structure to withstand the great strain brought upon it, more particularly, of course, by the big 12-inch guns. The vessel proved herself amply strong, no damage whatever resulting.

STERN VIEW OF THE "YASHIMA," STEERING WITH HELM A-PORT.

The torpedo tubes were also tried. Four of these, as mentioned previously, are submerged about 10 feet below water, and discharge their torpedoes on the broadside. It was therefore necessary to run the vessel at full speed to test the efficiency of these tubes, as it is then that the greatest pressure is brought to bear upon the torpedo as it leaves the ship's side, and upon the shield which is run out to protect it from the danger of being broken off by the water rushing past. The tubes of the *Yashima* and *Fuji*, which, in addition to all the rest of the armament, were designed and manufactured by Sir W. G. Armstrong, Whitworth & Co., all worked well, the torpedoes being discharged without difficulty at various speeds up to 17½ knots. This completed the severe course of trials to which the *Yashima* had to be subjected before being finally accepted and taken over by the Japanese Government.

All the trials were carried out by Messrs. Armstrong in the presence of the Japanese officers appointed to supervise them, including Captain Yendo, I. J. N.; the Japanese Naval Attaché, Captain Myabara, I. J. N.; Captain Fukuda, I. J. N.; Lieutenant Mera, I. J. N., and others, and Captain Arima and the other officers of the ship were also on board.

A BOW VIEW, WITH HELM A-STARBOARD.

Just before the final departure of the *Yashima*, whilst she still lay in the Tyne, Captain Arima and the officers gave an entertainment on board to all their English friends. This was most numerously attended. The ship was beautifully decorated by the crew, who also gave exhibitions of their skill in feats of arms and in various most ingenious devices for the amusement of their guests.

The *Yashima* finally left the Tyne on September 15, 1897, for Japan,—about a month later than her sister ship, the *Fuji*, and there can be very little doubt that the presence of these two splendid ships in Japanese waters will be a source of pride and satisfaction to all loyal Japanese who have now established themselves as one of the bravest and most enterprising naval powers of the world.

The illustration on page 288 shows the vessel undergoing her anchor trials. She is moving slowly astern and the port bower anchor has just been let go.

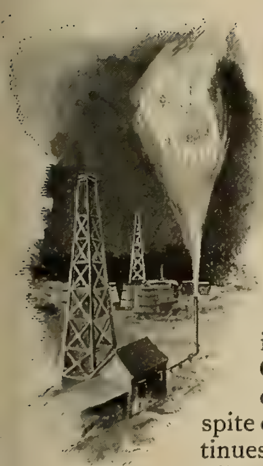
Before closing this article upon the *Yashima*, it should be pointed out that the Japanese naval programme is not by any means complete; the *Yashima* and *Fuji* are, in fact, only the forerunners of several first-class vessels now building and in contemplation,—vessels larger and superior in every way to any hitherto possessed by the Japanese Navy. Three first-class battleships of 15,000 tons are now being constructed in Great Britain, of a type similar to the *Majestic* class of the British Navy. One of these vessels is being built by Messrs. Armstrong at Elswick, one on the Clyde, and one on the Thames. There are also building for Japan five first-class armoured cruisers of nearly 10,000 tons displacement and 21 knots speed. Three of these vessels have been commenced at Elswick and the other two are building, one in France and one in Germany.

In addition to the four first-class ships named above, Messrs. Armstrong are also building for the same navy a fast cruiser of 4300 tons and 23 knots, similar to the famous *Yoshino*. The armament of all these vessels has been entrusted to Messrs. Armstrong, and they are all to be finished in less than three years.

NATURAL GAS IN THE UNITED STATES.

Its Transmission and Utilisation.

By Hosea Webster.



WHEN the industrial history of the last quarter of the present century is written, one of the most interesting chapters will be on the discovery and development of the few large accumulations of natural gas in the United States and Canada, and the almost criminal waste which, in spite of repeated warnings, continues to-day, and apparently will continue until, within probably a few years, these reservoirs of energy will be exhausted, and communities now hustling with energy and full of the hum of industry will be silent and perhaps deserted.

The estimates of the amount of energy stored away ages ago in the depths of the earth and to-day applied to heat and power generation and transmission will seem almost fabulous. The transformation of unproductive farm lands into wealthy centres of industrial enterprise almost in a fortnight will be told, and the chapter will close with a description of efforts to artificially produce a substitute for nature's great gift, which, for want of protective legislation against waste and want of even ordinary intelligence and care in most of its applications, will be but a tithe of the benefit to mankind that it might have been.

The origin, accumulation and properties of natural gas form one of the most interesting of the many fields for speculation in natural science. While its formation has been continuous, to a greater or less degree, since the first developments of organic life, and apparently is as extensive at the present time as it was at any previous age, its storage and retention in the vast reservoirs which are to-day being so rapidly emptied took place during a comparatively short period in the world's geological history. The reservoirs, or, more properly speaking the gas-bearing rocks, are located in the paleozoic strata from the upper coal measures down to the Trenton limestone, the most prolific being the Berea grit in the subcarboniferous and the Trenton limestone of the lower silurian age.

The accumulation of natural gas is analagous to that of the water supplying artesian wells, but in an inverse relation. Every richly productive gas pool is a dome or inverted trough, of porous or coarse-grained sand or limestone, geologically called an "anticline," and covered always by a deposit or stratum of impervious shale or similar formation. These anticlinals vary in area from a few square miles in most cases to over five thousand square miles in the case of the great Cincinnati arch which covers the Indiana and Ohio gas belts in the United States. The thickness of the strata varies in like proportion. The gas reservoirs are in no sense cavernous, but merely more or less porous rock, impregnated with gas, often under enormous pressures, the more porous rocks when pierced by the drill being exhausted much more quickly than those of closer texture.

No law has been discovered by which the location of gas-bearing rocks can be positively determined before drilling, and the limits of a field can be determined only when a sufficient number of

DRILLING A NATURAL GAS WELL.

non-productive wells has been drilled to indicate the boundaries.

Natural gas consists chiefly of hydro-carbons of the paraffine series, mixed with nitrogen, a small proportion of carbon dioxide and traces of oxygen.

The hydro-carbons, representing about nine-tenths of the volume of natural gas, are divided into two classes,—paraffine and olefine. Of the paraffines the most abundant is methane, or marsh gas, which consists of 25.03 per cent. hydrogen and 74.97 per cent. carbon by weight. It is the lightest of the numerous bitumens or natural carbon compounds, which include petroleum, asphaltum, graphite and the diamond. The specific gravity of marsh gas is 0.55297, one cubic foot at atmospheric pressure and 60° temperature F., weighing 212.36 grains. It liquefies at about 2700 pounds per square inch at 12° F., or at atmospheric pressure at 263° below zero. It requires twice its volume of oxygen or twelve times its volume of air for its complete combustion to carbon dioxide and watery vapour.

Its chemical composition, as shown by an average of analyses of four samples from Indiana and three from Ohio, by Prof. C. C. Howard, for the eleventh annual report of the United States Geological Survey, is as follows:—

Marsh gas, $C.H_4$	93.36
Nitrogen	3.28
Hydrogen	1.76
Carbon monoxide	.53
Oxygen	.29
Olefiant gas	.28
Carbon dioxide	.25
Hydrogen sulphide	.18
Total	99.93

The heat producing value of natural gas, as compared with other fuel gases per 1000 cubic feet at 40° F. and at atmospheric pressure, is approximately as follows:—

Natural gas	1,103,300	heat units
Coal gas	735,000	" "
Water gas	322,000	" "
Producer gas (heated)	156,000	" "

Assuming the generation of steam at 212° from water at 60°, the comparative value of natural gas per 1000 cubic feet at atmospheric pressure is approximately as follows:—

1000 cubic ft.	of natural gas	evaporate	900	pounds.
" "	"	coal	"	"	600	"
" "	"	water	"	"	250	"
" "	"	producer	"	"	115	"

As an illuminant it is used quite extensively, its candle-power varying in different fields, but averaging about one-half of ordinary commercial coal gas. Attempts have been made to enrich it for illuminating purposes, but no commercially successful results have been reached.

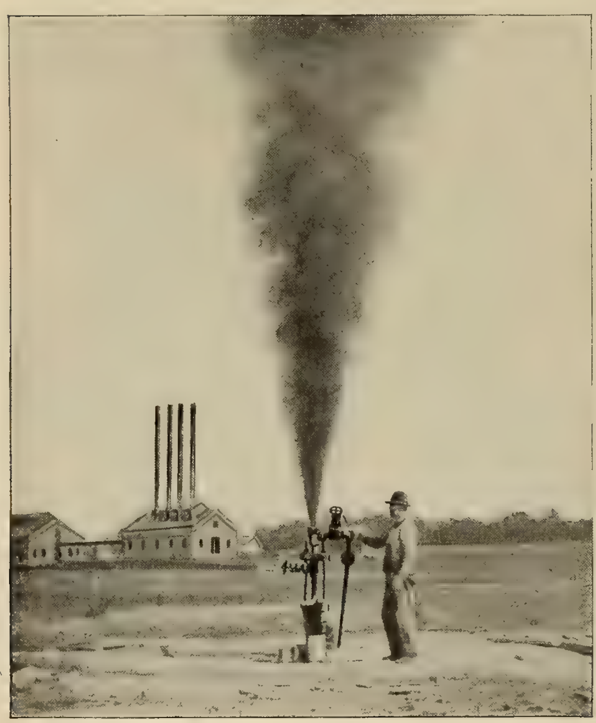
Many ingenious and interesting theories have been advanced regarding the generation and origin of the gas and designed to account for the great pressures under which it is stored. The distribution and intimate relation of the carbon compounds all favour the theory of their generation by the decomposition of vegetable and animal organic matter under widely different variations and surroundings of temperature, pressure and other forces and chemical influences, from the earliest developments of organic life to the present time. The gas is probably the product of slow primary decomposition, at low temperatures, of animal and vegetable organic matter contained in natural sediments. Its production may be seen in the shallow, undisturbed portions of fresh water lakes. Petroleum and the heavier bitumen deposits may be the products of decomposition of sedimentary deposits long contained under various combinations of pressure, temperature and structural deformation.

The deposits of oil and gas in the peculiar geological formations from which they are being drawn for commercial uses are due to the accidental disposition of the anticlinals and synclinals which act as reservoirs and do not necessarily indicate the restriction of their generation to any particular geological period.

A TYPICAL WELL, SHOWING THE USUAL PIPE AND FITTINGS.

In every gas-producing anticline deposits of oil and water are found in varying quantities, arranged in the order of their weight; first the light gas, then the oil and at the bottom water, always salty, and of a peculiarly char-

acteristic bitter taste. There has been much speculation as to the source of the gas pressure which prevails in the reservoirs and varies from 40 or 50 pounds in some fields to 1250 pounds in some of the West Virginia wells. The original generation of the gas in a confined space, the gradual settlement of the superincumbent rocks, or the flow of water from higher levels down along the gas-bearing stratum, may, any one of them, account for the great pressures. The experience with wells which have given out during recent years, or in which considerable reduction in pressure has taken place, affords almost positive evidence that the pressure is hydrostatic, and that the variations between different fields result from accidental structural arrangement. The heaviest pressures are found in wells tapping those gas rocks farthest below the sea level.



BLOWING OFF A WELL TO REMOVE DUST FROM CASING.

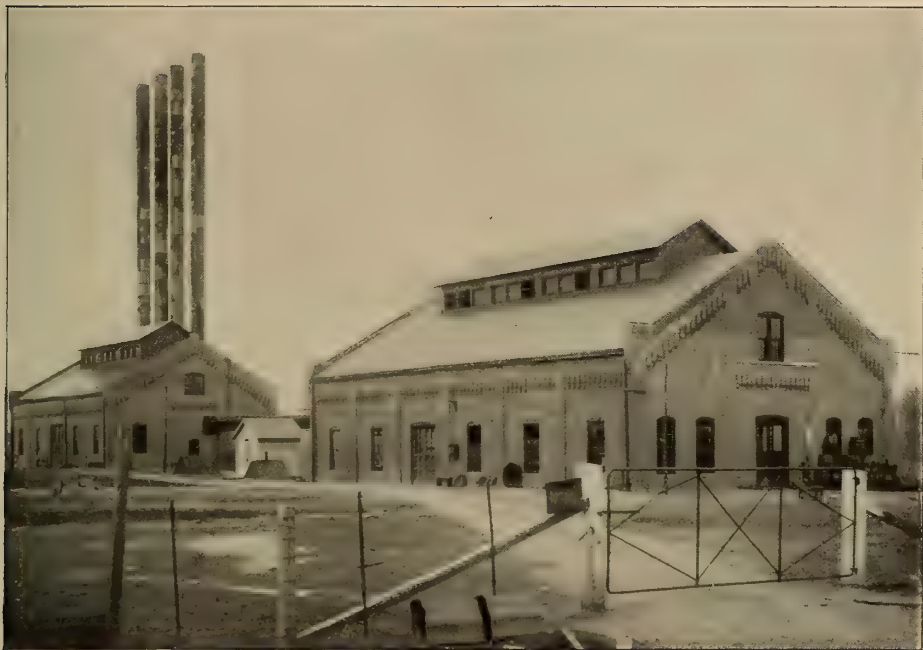
In the United States the strata of every geological age from the drift to the Potsdam have produced gas in a greater or less degree. The highest stratum in which it has been found in any considerable degree is in Pennsylvania in the Homewood sandstone, and the lowest is the Kane sand and the sand of the Roy and Archer gas pool in Elk county. Gas in commercially available quantities has been found in Arkansas, California, Illinois, Indiana, Kansas, Kentucky, Michigan, Missouri, New York, Ohio, Pennsylvania, South Dakota, Texas and Utah, and near Windsor and Niagara, in Canada.

The important fields at the present time are those near Pittsburg, including the Murraysville and Grapeville fields of Westmoreland county, and the fields of Washington, Greene, Butler, Alleghany and Beaver counties, in Pennsylvania. In Ohio the principal fields are near Findlay, and between Columbus and Newark. The greatest field known in the world is in the eastern central portion of Indiana, including over 2500 square miles in Grant, Howard, Delaware, Tipton, Hamilton, Madison, Hancock, Blackford, Henry, Marion, Shelby, Decatur, Franklin, Dearborn, Fayette, Wayne, Randolph and Jay counties.

As early as 1821 natural gas was taken from wells at Fredonia, in New York, for illuminating purposes. In 1872 the Newton gas well was struck and gas was piped through a 2-inch and a 3¼-inch line five and one-half miles to Titusville, Pa., and used for fuel and light purposes. In 1874 natural gas was first used in iron making by Messrs. Rogers & Birchfield at Leesburg, Pa. In 1876 a 6-inch main was laid seventeen miles from the Harvey well in Butler county, Pa., to Sharpsburg, and natural gas was successfully applied to iron working

in the mills of Messrs. Spang, Chalfant & Co., at that place.

In the vicinity of Findlay, O., natural gas has been present in springs and shallow wells since the earliest settlements, and for years it was regarded as a nuisance, ruining many wells and causing annoying and sometimes dangerous explosions in excavations. The first deep well in Findlay was begun by the Findlay Natural Gas Co. in October, 1884. Slight quantities of gas were encountered from a depth of 314 feet downwards, and at 1092 feet a strong flow was encountered.

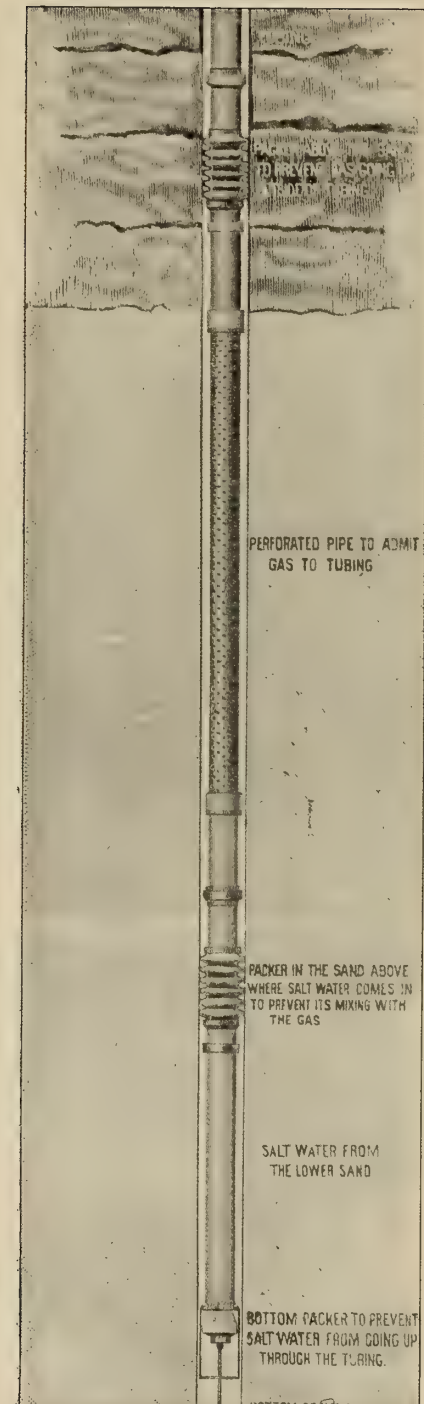


A TYPICAL GAS PUMPING STATION.

The opening of this well started the first gas boom at a time when the city of Findlay comprised four square miles and less than four thousand inhabitants. In 1885 and 1886 there was a steady growth and accession of enterprises and industrial works, but with the spring of 1887 began a most remarkable and exciting boom and speculative activity, which, in a few months, extended the city limits until the original four square miles had spread to twenty-four. A census in the spring of 1887 showed 10,221 persons residing within the original city limits. Farms were turned into city lots and sold for five times the prices asked in 1886. The census of 1890 gave Findlay 18,558 inhabitants.

In 1876 a coal prospect hole was drilled at Eaton, Delaware county, Ind., to a depth of 600 feet, obtaining some gas, but the well was abandoned. In 1886 a company, formed to prospect for natural gas, let a contract for deepening this well. It was drilled to 920 feet below the surface, striking the Trenton limestone, into which it was bored 30 feet, giving a flow of 2,500,000 cubic feet of gas per day. Mr. A. H. Crannell, the contractor, enjoys the distinction of drilling the first natural gas well in Indiana and opening the greatest field in the world.

In drilling for gas the same outfit is used as in drilling for oil, and on completion of the well, the derrick and the appliances are moved away and used



PACKING FOR THE BOTTOM OF TUBING.

again on the next well instead of being left as in the oil regions. Nothing remains but a short projection of six or eight-inch pipe, with a few fittings and connections of small dimensions, suggesting to the uninitiated an abandoned artesian well.

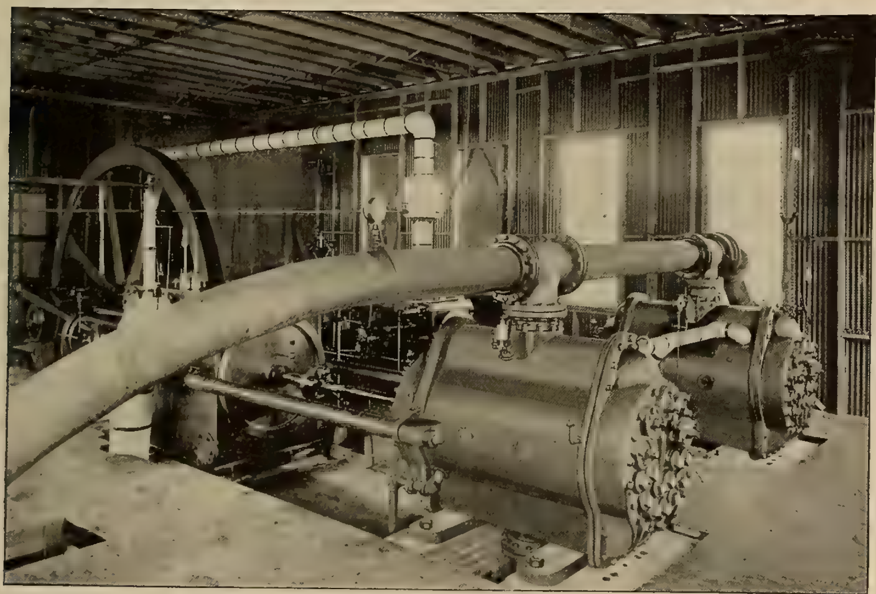
Passing through a gas belt one will see near the roadside, in a farm lot, a mud-bespattered, weather-beaten derrick, with the apparently rickety accompaniment of crude appliances made familiar years ago in the oil regions,—a small reversing engine, a rusty locomotive boiler, usually without a stack and leaking at every seam; the ponderous wooden walking-beam slowly oscillating night and day, stopping only to give place to the use of the bull wheel when the drill is raised and the sand pump is lowered, or a newly dressed bit is put in service. Crude as the rig and all its details may seem at first glance, every part is soon seen to have its use, and the journey of the bit from the surface to the unknown, and perhaps barren, depths, is always accompanied by interesting and ever-varying developments. At night the measured beat and clatter of the rig in the dim light of a few flickering torches of gas, piped from some neighboring well; the trembling derrick, its lofty top lost in the darkness; the driller carefully manipulating the temper screw after each stroke, controlling the bit at the end of a rope perhaps half a mile below the surface, all form a weird sight. Accidents are frequent, and the slightest carelessness may result in dropping the tools, the recovery of which requires patience and often great ingenuity.

The wells usually are started with an 8-inch hole, which is fitted with wrought iron pipe, through the drift to the bed rock. Through the succeeding strata a 5⅝-inch hole is drilled and fitted with a wrought iron casing down to the solid, impervious stratum located just above the gas-bearing rock, through which the drill is run without any casing into the gas rock. Upon the developments at this point depend the next steps. A mixture of oil and salt water may be encountered with the gas, and many

ingenious expedients are adopted to separate them.

The gas is brought to the surface through 2½ or 3-inch wrought iron pipe, at the bottom of which is placed an arrangement of so-called "packers" to make a gas and water-tight joint between the pipe and the solid, impervious rock wall of the drill hole, and, if water and oil are found in the gas rock, to keep them from flowing up from the lower end of the pipe. The general style of the many types of packers is the same. A hollow cylinder of rubber, smooth or ribbed on the outside, and as large as can be put in the well, is held above and below by a slip joint. When the tubing rests on the bottom of the well, the weight of its upper part forces the top flange upon the rubber, distending it against the sides of the well, and thus making a gas and water-tight joint.

At the surface end of the tubing three valves are placed and arranged so that the well may be blown out into the air, or shut off from the service main, which is also blown out from time to time. Before confining the gas by closing these valves, the tubing is anchored down by clamps and ties to the top of the 8-inch casing. In spite of every precaution, attempts to control the gas are often followed, where great pressures are encountered, by the lifting of the tubing casing and all from the ground. Instances are recorded of wells remaining uncontrolled for over a year. Occasionally it is found impossible to exclude all the water by the packers at the bottom of the well. A small pipe is led to the bottom of the tubing and brought out at the top where the water is forced up and out of the well by the gas pressure.



A NATURAL GAS COMPRESSOR OUTFIT AT THE WORKS OF THE PITTSBURGH PLATE GLASS COMPANY, BUILT BY THE NORDBERG MANUFACTURING COMPANY, MILWAUKEE, WIS.

From the well a 2-inch or 2½-inch pipe is run to the point of consumption, or as a feeder to a main which, supplied from many wells, runs across the country to some town, often miles away, where the gas is distributed to factories, dwellings and office buildings.

The depth of the wells varies greatly in the different fields, the widest variations being in the Ohio and Pennsylvania districts, while in Indiana it is

more uniform. The best wells in Indiana are about 1000 feet deep, and, as a rule, tap the Trenton limestone less than 100 feet either way from sea level. In Pennsylvania and Ohio, wells are much deeper below sea level. A geological section of Indiana rocks along a line from Delta, O., to Terre Haute, Ind., passes through the most productive region.

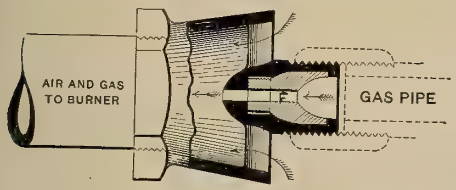
When the flow from a well is shut off, the pressure at the surface rises, sometimes gradually, often in a few moments, to the natural or rock pressure. The pressure so attained varies in different fields, always decreasing with the age and use of the well and the field. In Pennsylvania the highest pressure recorded was at Castle Shannon, where 1020 pounds were observed. Near Columbus, in Ohio, a maximum of 800 pounds was observed; at Findlay, O., 450 pounds were noted, and in Indiana the rock pressure originally varied but little from 320 pounds. Measurements of the volume of flow from wells show variations from 100,000 to over 12,000,000 cubic feet per day.

The transportation and delivery of the gas from the fields to consumers has required enormous quantities of pipe. The feeders from the wells are of wrought iron, while the mains, from four to twenty-four inches in diameter, are of cast, wrought or riveted pipe, as the case may be. Statistics from the reports of the United States Geological Survey show that in 1893 and 1894 alone two hundred and four companies, reporting from Ohio, Pennsylvania and Indiana, laid 39,127,510 feet of all sizes of pipe. Owing to the dangerous qualities of the gas, great care in the design and application of fittings is necessary. In Pennsylvania, where the gas has little or no odour, the detection of leaks was impossible, and in the earlier days fires and fatalities were numerous.

A BOILER PLANT BURNING NATURAL GAS.

The manufacture of fittings and appliances for natural gas is an industry by itself. Leakages are always serious matters, requiring prompt attention.

A leak in an underground main will destroy all vegetation within a radius of several yards, and, when unchecked, will, in some fields, form a deposit in the soil beneath the joint, which, when

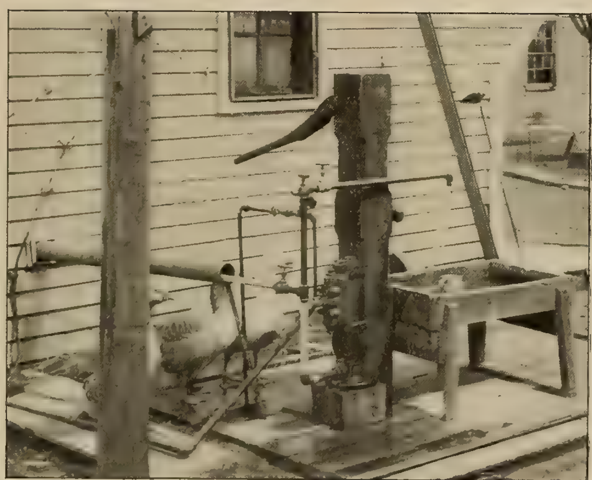


A "MIXER."

The small ferrule F is of hardened steel, set in loosely, and free to turn, and is designed to prevent boring out the mixer so as to get more gas than intended.

exposed to the air, will ignite spontaneously and can be put out often only with great difficulty.

While in transporting gas over long distances, from the field to the point of consumption, — often from 40 to 50 miles,—much of the natural pressure is lost in overcoming friction, the pressure in the distributing mains must be carefully controlled or regulated at various points from time to time to meet the requirements of consumption. This is done at the outskirts of a city, at reducing stations, where automatic pressure controllers or reducing valves, of various patterns, but mostly of the counterbalanced diaphragm type, maintain pressures from 50 to 10 pounds in the distributing mains. At each consumer service pipe is placed a low-pressure regulating valve which still further reduces the pressure to about 8 or 10 ounces.



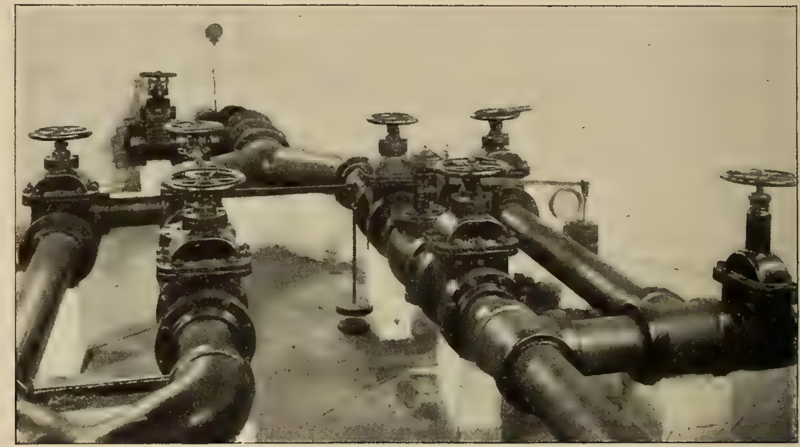
A PUMP DRIVEN BY NATURAL GAS PRESSURE.

Previous to consumption the gas must be mixed with from ten to thirteen times its volume of air, which is accompanied by "mixers" in which the velocity of the jet of gas from a small orifice draws in the requisite amount of air on the principle of the Bunsen burner. From the mixer, which is usually outside of the stove or furnace, the mixture of air and gas is conveyed by a pipe to the burner.

For household purposes these mixers vary in size. The orifice of the jet for the gas is from $\frac{3}{32}$ to $\frac{3}{16}$-inch in diameter, and permits the consumption of from 40 to 250 cubic feet of gas per hour at from $\frac{3}{16}$ to 1 inch water pressure. In manufacturing establishments where gas is usually sold by meter measurement, efficient forms of mixers and burners are used, but in localities where charges are regulated by the number of burners or the number of stoves and furnaces in use, the matter of first cost is about the only consideration, and enormous, and often dangerous, wastage is the rule.

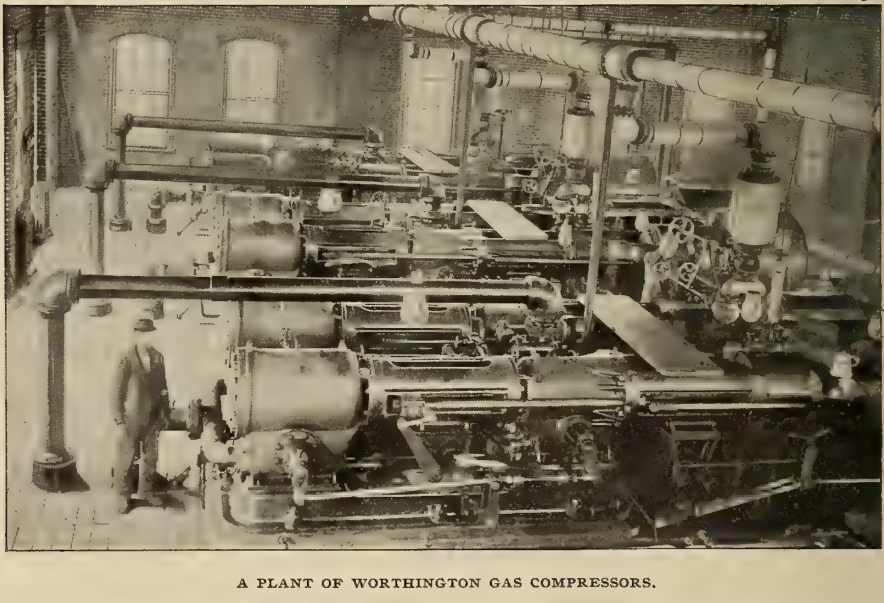
The orifices of the mixers are often bored out, and many times the mixers are removed entirely, and the gas is burned from the open end of a pipe, resulting in incomplete combustion and overtaxing the capacity of the supply mains. While in Ohio and Pennsylvania nearly all services are metered under laws of the municipalities, there are few places in Indiana where meters are used on small consumers' services. The result is an enormous, careless and

unscrupulous consumption of the gas, which is rapidly reducing the natural pressure. Gas jets, flambeaux and fires are left burning at all times, night and day, to save matches and to avoid the trouble of relighting.



ARRANGEMENT OF VALVES IN A PRESSURE REDUCING STATION.

In the eighteenth annual report of the ndiana State Geologist, Mr. E. T. J. Jordan, supervisor of natural gas, says: —"The time is fast approaching when the entire quantity of natural gas will be exhausted. Within the fields of Indiana, as well as in the rich areas of other States, this end has been hastened and brought in sight all too soon by the reckless extravagance and waste that has been practised. Within the Indiana field, alone, during the first years of gas developments, it can be shown that 100,000,000 cubic feet of this inestimable fuel were wasted every day.



A PLANT OF WORTHINGTON GAS COMPRESSORS.

Even at the low prices that have obtained in this area, the waste to the

present time would amount to upwards of twenty millions of dollars."

Most of the companies lease from farmers in the gas belt the privilege of boring wells, paying usually an annual rental and furnishing, free of cost, such gas as is wanted for fuel, light and for pumping, either by using the gas under pressure to drive the ordinary type of vertical or deep well pump or by application of a crude arrangement working the same as the well-known Pohlé air lift. The distribution and service pipes in the farming districts are seldom laid underground, except at road crossings, and are usually ½-inch or ¾-inch pipes, now running along the roadside, now hanging on the fences.

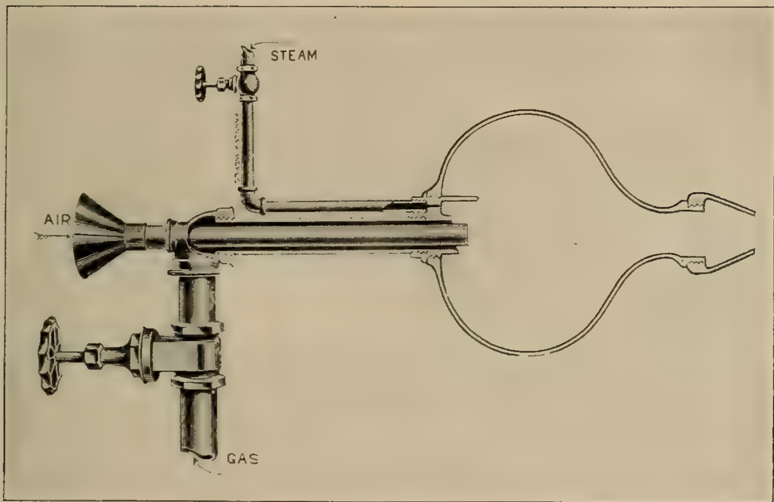
An occasional small pile of stones, covering one of these pipes, shows where some tramp, having cracked a pipe or a joint, has built a cheerful fire which needs no replenishment and makes of the weary pilgrim a veritable fire worshipper.

The maintenance of the system of collecting and distributing mains, gathering the gas from wells scattered over several square miles and distributing it again to perhaps thousands of consumers in some city, thirty or forty miles away, requires the most careful and systematic attention and inspection. Each well has its individual idiosyncrasies and no two are alike in volume of flow, pressure or presence or absence of water, oil or dust.

An unrestricted flow from one well might, by raising the pressure in the receiving mains above that available from some other well, lessen or reverse the flow of that one, and frequent gaugings are necessary to ensure the most efficient service from the system.

Accumulations of dust, paraffine, water and oil in the mains are guarded against by "blowing" the wells and the mains and by traps or catch basins. In some fields the accumulations removed from mains or catch basins frequently catch fire spontaneously on exposure to the air.

When it is realised that natural gas is almost identical with the miner's dreaded fire-damp, the dangers attending its collection, distribution and consumption may be appreciated. There is sufficient sulphuretted hydrogen in the Indiana and Ohio gas coming from the Trenton rock to make its presence in the smallest quantity quickly apparent, but the Pennsylvania gas is frequently without odour, making the



SECTIONAL VIEW OF A NATURAL GAS BURNER FOR BOILER FIRING, MADE BY THE CLAYBOURNE BURNER COMPANY, CHICAGO.

strictest inspection and testing of all pipe work necessary.

In Pennsylvania and Ohio gas is usually sold by meter measurement, at prices averaging about twenty-five cents (1s.) per thousand cubic feet, while in Indiana, with the exception of a few cities, meters are not used, except by permission of the consumers, charges being usually regulated by the number, size and type of burners in use.

The average rates for different uses for fifteen cities in Indiana are as follows:—

Cooking Stoves.		Heating Stoves.		22" Furn.	Grates.	Grates.	26" Furn.	Ranges.	Ranges.
Monthly rate Oct. 1 to May 1.	Annual Rate.	Monthly rate Oct. 1 to May 1.	Annual Rate.	Residences, Annual rate.	In Residences, Annual rate.	In stores and business houses Annual rate.	Hotels, etc. Annual rate.	Restaurants, Annual rate.	Hotels. Annual rate.
$2.28 8s. 1½d	$21.40 £4 5s. 7½d.	$2.75 11s.	$17.12 £3 8s. 6d.	$35.85 £7 3s. 5d.	$18.35 £3 13s. 5d.	$22.85 £4 11s. 5d	$41.40 £8 5s. 7½d.	$41.40 £8 5s. 7½d.	$75.00 £15

Special forms of meters are in use where gas is metered to consumers. They usually have cast iron, or sometimes composition, shells, as the pressures are too high for the ordinary tin meters used for artificial gas. In gauging the flow of gas through the large mains under heavy pressures the Pitot tube is used. This instrument is a modification of an instrument named after the inventor who first described its use for measuring velocities of flow in rivers, before the Academy of Sciences in 1732. Its readings, after careful checking by standard meters, have been found to be quite accurate, and it is extensively used in all gas fields.

Statistics.

The statistics of natural gas, as given by the late Joseph D. Weeks in the sixteenth annual report of the United States Geological Survey, afford a very good idea of the importance of this wonderful natural product. From the earliest extensive use of gas at Findlay in 1884 the value of gas consumed in Ohio rose from $100,000 (£20,000) per annum to $5,215,000 (£1,403,000) in 1889, when the production gradually fell off to $1,276,000 (£255,200) in 1894, the total value for the ten years being nearly $20,000,000 (£4,000,000). In Pennsylvania the greatest annual output was in 1888, valued at $19,282,000 (£3,856,400), with a total for the ten years from 1885 to 1894, inclusive, of $95,654,186 (£19,130,837).

In the list of values of non-metallic mineral products of the United States, natural gas stands fifth in the list, being exceeded by bituminous coal, anthracite coal, bluestone and petroleum only, and valued for the ten years, from 1885 to 1894, inclusive, at $159,907,297 (£31,981,459). Mr. Weeks estimated the total consumption of natural gas in the United States in 1889 at 552,150,000,000 cubic feet. Assuming 30,000 cubic feet of gas to be equal in heating power to one ton of Pittsburgh coal, this represents an equivalent of 18,405,000 tons of coal. The appliances used for the consumption of natural gas are so cheap and crude, and, with few exceptions, so inefficient, that it is safe to say that less than one-half of the possible heat-producing capacity of the gas consumed has been realised.

Reports received from twenty-one counties, covering 2507 square miles in the Indiana field, show, for 399 wells, an aggregate daily flow of 779,325,000 cubic feet, which, if efficiently consumed, would generate sufficient steam to supply over one million indicated horse-power of compound condensing engines.

As the consumption of gas goes on, the natural or rock pressure decreases, many wells becoming useless, often by the flow of more water than can be separated and often by the inflow of oil. In the Findlay, O., field the original

pressure of about 450 pounds has fallen to less than 150 pounds. In Pennsylvania, where the original pressure was about 500 pounds, it has fallen in most places to nearly 50 pounds. In Indiana, where the field is comparatively new and where many wells showed at first 340 pounds, the pressure has dropped to an average of about 240 pounds.

As the pressure falls off and the consumption increases, mains which were of ample size have proven too small for supplying the gas, and the loss of pressure has made necessary the use of pumps to augment the natural pressure. The first use of pumps was by The People's Company of Pittsburg, which had two plants in operation in the winter of 1890 and 1891. Since that time nearly all the companies supplying large cities at a distance from the fields have resorted to pumping plants, most of which lie idle during the summer months and run only during the time of year when fires are required to warm the houses, stores and factories.

Standard forms of air compressors are used for the purpose. In some cases the compressors are driven by compound or even triple expansion condensing engines, not so much for fuel saving purposes as for saving in original first cost in the boiler plant required. In some parts of Pennsylvania the gas has become so scarce at the pumping plants that coal is used for fuel under boilers operating the gas pumps.

The forcing of large quantities of gas through long mains by means of pumps gives an interesting illustration of a method of transmission of power. One pumping plant which delivers gas at atmospheric pressure to the city of Indianapolis, Ind., at the rate of 1,500,000 cubic feet per hour through about 30 miles of 10-inch main, requires less than 1800 commercial horse-power of boilers to operate the pumps. The gas which comes to the pumping station from the gas field at a pressure of 100 pounds per square inch is raised to 300 pounds by the engine at the station, and this is reduced by friction to nearly atmospheric pressure when it reaches the city, where it could supply fuel for the operation of 60,000 horse-power of compound condensing engines.

The rapid decrease of the supply of natural gas has forced the consideration of means of artificially producing a gas which can eventually take its place, or supply the greatly increased demand during severely cold weather, and so keep in use the extensive distributing pipes already installed. Such a gas must be a fixed gas, must readily mix with natural gas, and must be high in heat units and readily combustible.

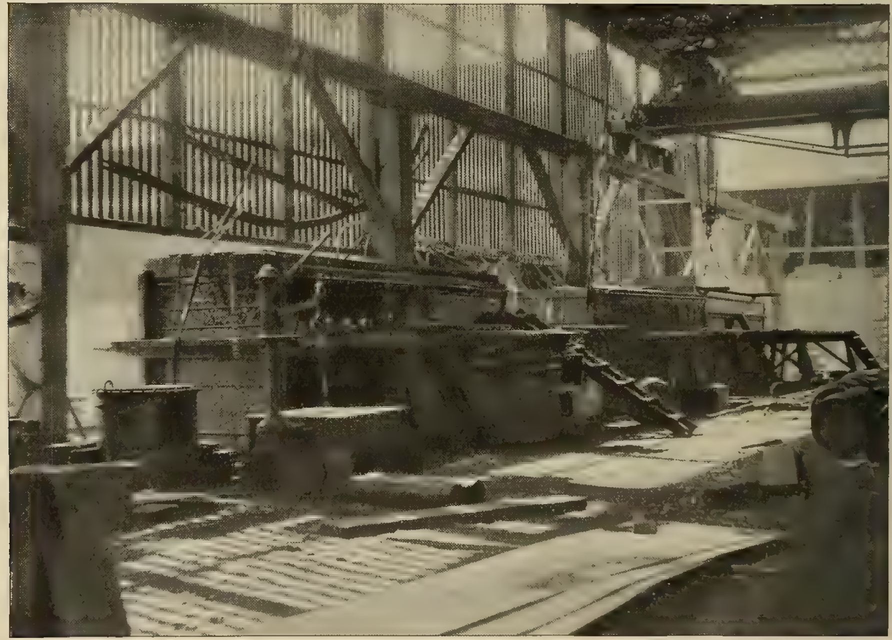
Most of those who have experienced the comfort and convenience of natural gas, both for domestic and industrial purposes, will, undoubtedly, gladly pay more for artificial substitutes rather than return to the use of coal, and the near future is likely to see a rapid development of methods of generating a high grade of fuel gas. The day is not far distant that will witness the establishment of enormous fuel gas plants in the coal regions to utilise what are now becoming almost mountains of waste material. Huge compressors will force the gas through miles of mains to the distributing pipe systems, and, coupled with the luxury of electric light, will come the cleanly, convenient and no less luxurious use of fuel gas for all purposes.

RECENT IMPROVEMENTS IN ELECTRO-GALVANISING.

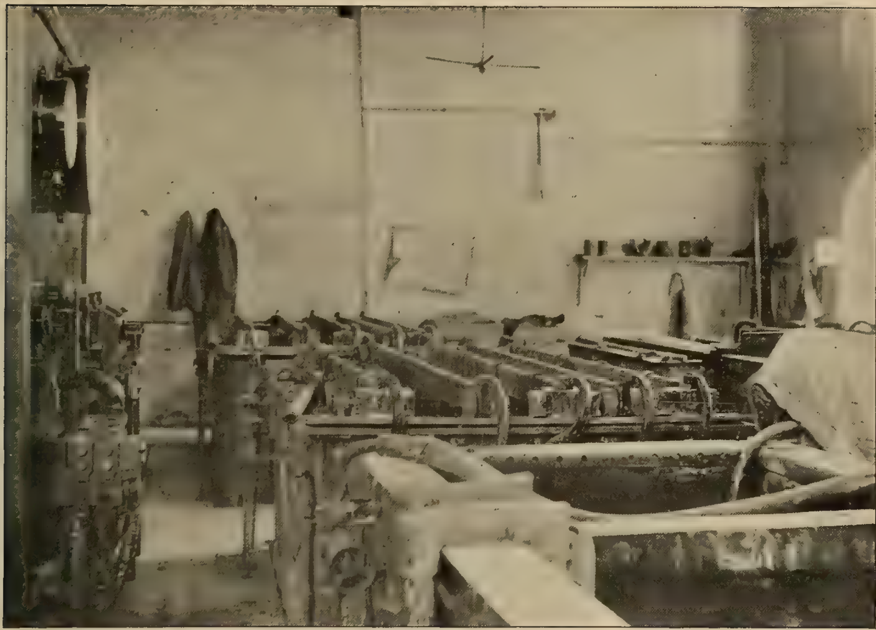
By Sherard Cowper-Cowles, Assoc. M. Inst. C. E.

THE ordinary method of galvanising, consisting, as it does, in the immersion of the articles to be coated in a bath of molten zinc, is a wasteful process. In the first place, the large quantity of zinc, usually about 20 or 30 tons, which has constantly to be kept in a molten condition, entails a heavy expenditure in fuel. The strong tendency of iron and zinc to form an alloy leads to the rapid corrosion of the baths, which, on an average, require renewing every six months. The zinc-iron alloy which forms in the bath of zinc, amounting in some cases to 25 per cent. of the whole amount of zinc used, also causes considerable loss to the galvanisers. The hot process has the further disadvantage of reducing the strength of iron, and of distorting and rendering brittle iron and steel of small sections. In many cases it is found necessary to re-hammer or bend the plates after galvanising, and this treatment causes the zinc to flake off when the adhesion is poor.

Attempts have been made at various times to substitute ordinary electro-zinc plating for galvanising, but until recently the attempts have not been successful, as the process was found to be too slow and costly, and the zinc coating thus



ELECTRO-GALVANISING PLANT AT THE SHIPYARD OF MESSRS. LAIRD BROS., BIRKENHEAD, ENGLAND



A SIMILAR PLANT AT THE WORKS OF MESSRS. MAUDSLAY, SONS & FIELD, LTD., LONDON, FOR COATING TUBES FOR BELLEVILLE BOILERS.

obtained, porous. This cold galvanising, zinc plating, or flashing is now, however, being adopted by shipbuilders, as large plates can be coated very economically, and a large number of the torpedo boat destroyers recently built for the British Admiralty have been electro-zincked.

The illustration on the opposite page shows a plant erected at the shipyard of Messrs. Laird Brothers at Birkenhead, England, capable of electro-galvanising plates and angle irons up to 20 feet in length, whilst the illustration above shows a plant at Messrs. Maudslay, Sons & Field's Greenwich Works, designed especially for coating the tubes of Belleville boilers.

Many experiments have been carried out at different times with the object of cheapening the process of coating iron with zinc, and of avoiding the deterioration of the quality of the material which usually follows pickling and hot galvanising, as the records of the Patent Office bear ample evidence. Amongst the improvements made are those based upon electrolytic methods. Most authorities recommend a current density of 15 to 20 ampères per square foot of cathode surface, with an electro motive force of three volts at the terminals of the depositing bath, the solutions employed being zinc sulphate, acetate, or

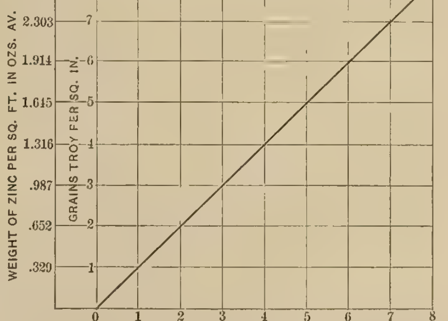


DIAGRAM SHOWING THICKNESS OF ZINC REQUIRED TO WITHSTAND A VARYING NUMBER OF ONE-MINUTE IMMERSIONS IN SATURATED COPPER SULPHATE SOLUTION.

chloride, ammonium chloride or tartrate.

The author has obtained good, bright deposits from a solution composed of

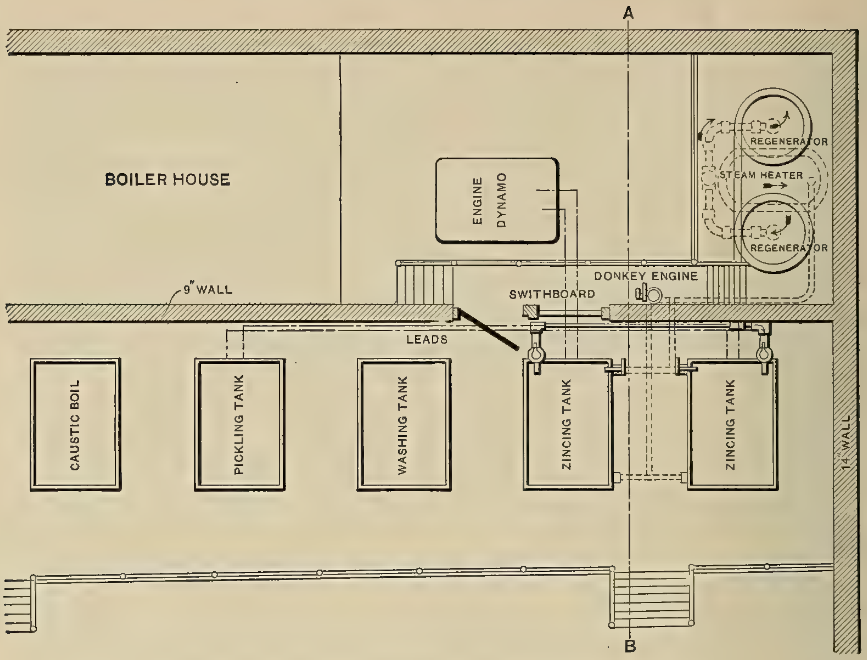


FIG. 1—A PLAN OF AN ELECTRO-GALVANISING WORKS.

40 ounces of zinc sulphate (sp. gr. 1.1770=19 per cent. of crystallised zinc sulphate) and 5 ounces of ferrous sulphate to the gallon of water, the anodes being of lead. The iron salts should be brought to the ferric condition, as no deposit of iron can be obtained from a solution of a ferric salt. The generation of hydrogen at the cathode reduces the salt to the ferrous condition, which is again converted into the ferric by the corresponding oxygen liberated at the anode; the formation of zinc sponge is thus considerably reduced.

Thin coatings of zinc, obtained from acid solutions, under favourable conditions are very adhesive when proper care is exercised in the preparation of the receiving surface. Specimens of zincked iron plate have been double folded, and boiler tubes have been reduced under the steam hammer to one-fourth their original length, the zinc coating being still intact, the weight of zinc per square foot averaging about ¾ ounce. Electro-deposited zinc appears to adhere better to surfaces which have been cleaned with the sand blast than to surfaces which have had the scale and oxide removed with acid.

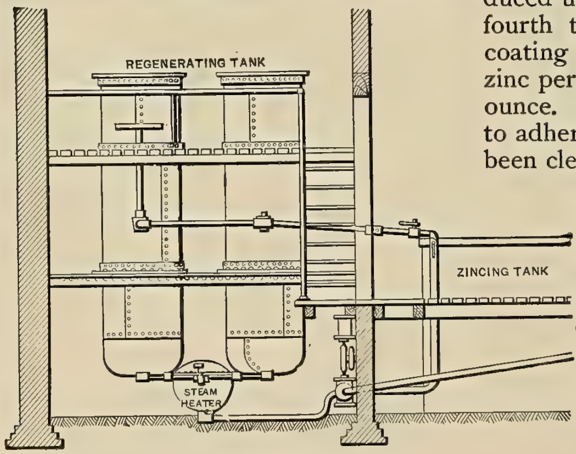
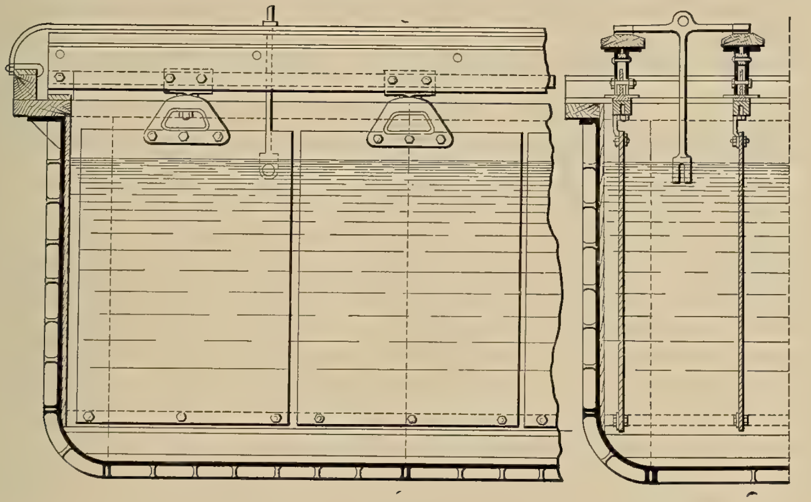


FIG. 2—SECTIONAL ELEVATION.

When zinc is deposited of a thickness corresponding to more than 1½ ounce per superficial foot, upon iron or steel, it does not form a continuous adherent coating. Attempts have been made to overcome this difficulty in the

same way as the want of adhesion in silver-plating was overcome, by quickening—that is, immersing the copper or copper alloy in an aqueous solution of mercury; but in the case of iron the mercury has to be deposited electrolytically, as the iron will not amalgamate with the mercury. Under unfavourable conditions the zinc coating is of a transitory nature, its durability being incompatible with hot galvanising, as the deposit is porous and retains some of the acid salts which cause a wasting better, than zinc applied by the hot or dry method. The diagram on page 307 shows the thickness of zinc required to withstand a varying number of one-minute immersions in a saturated copper sulphate solution. Other matters of serious moment are the slowness of ordinary electro-zincking, the trouble experienced in coating articles of irregular shape, and the difficulties occasioned by the formation of loose, dark-coloured patches. These difficulties and the unhealthy non-metallic look of the zinc



FIGS. 3 AND 4—SECTIONAL SIDE AND END ELEVATIONS OF ELECTRO-GALVANISING TANKS.

of the zinc and rusting of the steel or iron.

Specimens of zinc deposited from an acid zinc sulphate solution, which have been stripped from bright rolled steel, when held up to the light, will be seen to be pierced with a number of small holes. On the other hand, zinc can readily be deposited free from pin-holes, and ductile, having more the properties of rolled instead of cast zinc, when the proper current density and strength of solution are carefully maintained. The presence of free acid appears to accelerate the formation of zinc sponge.

Zinc, electro-deposited upon iron and steel, is found to resist the corroding action of a saturated solution of copper sulphate (this is the British Post-Office test for telegraph wires) as well, if not

coating obtained by the humid process, its want of brilliancy and glitter, has prevented ordinary electro-zincked articles from finding favour with engineers and the trade for many purposes.

Troubles are also experienced from the scaling and furring up of the anodes, the electrolyte constantly getting out of order when working with a large current density, as more metal is taken out of the solution than can possibly be dissolved from the anodes, on account of the rapid formation of an insoluble scale on the surface of the anode. The scale is constantly peeling off, and has a tendency to settle on the cathode, spoil the zinc deposit and form a thick sludge at the bottom of the depositing tank, rendering it impossible to circulate the electrolyte freely. The loss of

zinc in many cases amounts to 30 per cent.

Figs. 1 and 2 show a plan and sectional elevation of a plant suitable for depositing zinc upon iron sheets. Two steel tanks are provided for containing the electrolyte, which is circulated through the regenerating tanks by means of a small donkey pump or a steam injector, the connections being so arranged that the regenerating tanks can be charged and discharged alternately. In the regenerating tanks zinc dust is placed from time to time, which is dissolved by any free acid present.

The spent electrolyte is passed through a steam heater (shown in the sectional elevation, Fig. 2) before being injected into the bottom of the regenerator; the revivified liquid, as soon as the undissolved zinc dust has had time to settle, is allowed to return to the depositing tanks by gravity. The author has found the addition of zinc dust to the electrolyte to be the only practical method of keeping the electrolyte in working order, as zinc anodes, whether cast, rolled, amalgamated, or in the form of granulated zinc, fail to keep the solution up to its normal strength. The anodes which give the best results when working with zinc dust are lead. The economy effected by the use of zinc dust is considerable, as it can be obtained £7 or £8 per ton cheaper than rolled zinc anodes.

Figs. 3 and 4 illustrate a very convenient method of arranging the anode and cathode suspension bars, enabling the electrodes to be brought much closer together than would otherwise be the case; it also reduces the first cost of the plant, and forms a very stiff girder, which is an important feature when dealing with tanks 30 feet long.

The capacity of the dynamo for such a plant as shown in Figs. 1 and 2 would be 4000 ampères at an electro-motive force of 7 volts, the current being conveyed to the tanks by bare copper strips having a sectional area of one square inch for every 1000 ampères.

MECHANICAL STOKERS.

Their History and Development.

By William R. Roney.

FUEL and labour are the principal items of expense in nearly every industry in which capital is engaged, and the ratio which they bear to the total cost of production is very frequently the measure of the profit there is in the business. This is equally true of the mill, the factory, the railroad, the shop, and the electric power plant. It is not strange therefore that devices for saving fuel or labour are rapidly adopted as their merits are demonstrated.

With such encouragement new devices with more or less merit are continually being brought forward to advance economy in the boiler room. Improved furnaces and boiler settings, new forms of grate bars, new and varied methods of introducing air for supplying the necessary oxygen for combustion, and devices for delivering the fuel to the boilers, have multiplied rapidly; but with all their merits, each, used alone, falls short of accomplishing for boiler room economy what can be obtained by the use of a good mechanical stoker, which, if properly designed, combines the advantages of all these devices.

The use of machinery for stoking fuel under boilers is quite old, dating back over 100 years. The most extended use has been reached in Great Britain, where over 25,000 mechanical stokers are in service, built in many forms, but principally designed for stoking internally fired boilers, where the gates are usually flat, long and narrow. Most forms of British stokers embody the features of throwing or pushing the coal onto the grate by revolving fans and beaters, shovels, or plungers, located in the bottom of a hopper attached to the boiler front. Travelling chain grates, or rocking or reciprocating parallel bars carry the coal from the feeding mechanism at the front end of the furnace and discharge the ash and clinkers into a space provided in the rear. A few modifications of these have been brought to the United States; but being designed especially for internally fired boilers, their success has been but limited when applied to American externally fired boilers.

The earliest form of mechanical stoker of which there is any record was the one patented in 1785 by James Watt, the inventor of the steam-engine. It consisted of two sets of horizontal grate bars, one behind the other, which were worked intermittently by means of levers operated by hand. The coal was fed in at the door and pushed back as it became coked, the gases from the fresh fuel passing over and through the fuel in more advanced combustion at the bridge end of the grate. It was designed primarily to prevent smoke from bituminous coal and was quite successful.

The next mechanical stoker was invented by Dowson, in 1816, and was of the "under-feed type, and operated by a piston so as to keep a hot fire on the top of the bed of fuel."

The next mechanical stoker of which there is any record was invented by William Brunton, of Birmingham, England. This was patented in 1819. It consisted of a circular grate revolving on a central vertical spindle, and a hopper containing a toothed roller, so placed as to discharge the coal upon the slowly revolving grate. It is said to have worked quite satisfactorily. Three years later, in 1822, Brunton invented also a form of "coking-stoker," with pushers for feeding, and movable grate bars for advancing the coal when coked towards the bridge. He was followed by nearly 200 patents covering modifications of his "coking stoker."

In 1822 John Stanley patented the first, so-called, "sprinkler stoker," consisting of a hopper on the front of the boiler, fitted with rollers for crushing the coal, and rapidly-revolving beaters or vanes for distributing it over the grate. His patent drawing shows the stoker as applied to a "waggon boiler." Later, in 1834, J. G. Bodmer patented a form of mechanical stoker in which the coal was fed from a hopper on to an ingeniously designed grate in which the bars were slowly moved inward, and on reaching the bridge were dropped in sections and returned to the front of the furnace by means of return screws. This was really a modification of Brunton's coking-stoker, and, though ingenious, was complicated and too liable to get out of order to be practicable.

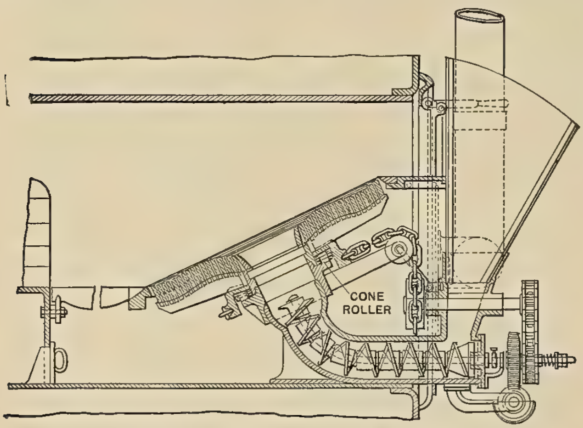


FIG. 1—THE HOPCRAFT STOKER, MADE BY THE HOPCRAFT FURNACE COMPANY, LONDON, ENGLAND.

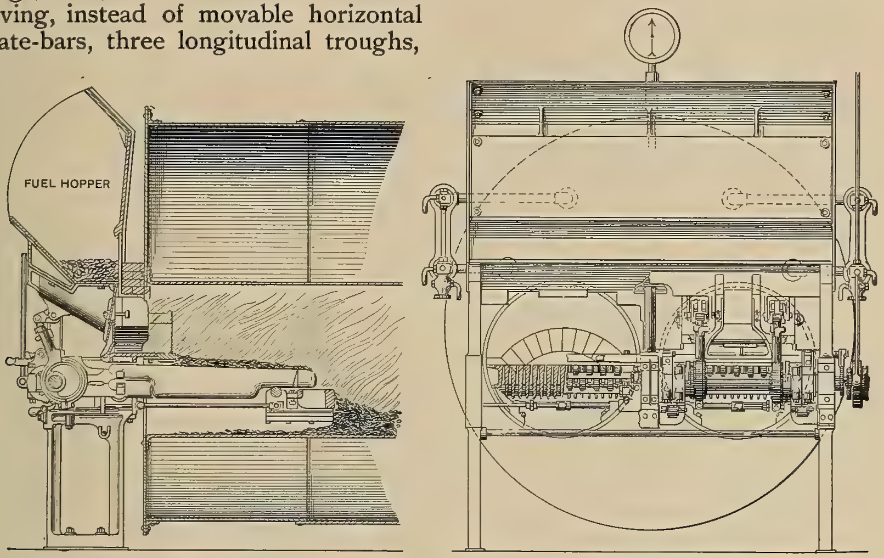
Of the many styles of mechanical stokers patented in Great Britain after the year 1841, nearly all were variations and modifications of the crude ideas shown in the "coking stoker" and the "sprinkler stoker," patented in 1822 by Brunton and Stanley, respectively. Among the earliest of these were the stokers patented by John Jukes in 1841, and E. Henderson in 1843.

The Jukes stoker consisted of a grate made of short parallel bars, connected by links, so as to form an endless belt, somewhat similar to the familiar treadmill horse-power. The coal was delivered from a hopper attached to the front end of the boiler, onto the grate, which, slowly moving from front to rear, gradually advanced the fuel and discharged the ash and clinker into the pit at the back. This stoker became quite popular and large numbers were introduced, principally because of its efficiency as a smoke preventer. It gradually fell into disuse, due, doubtless, to the fact that it was deficient in power, not economical of fuel, and costly to maintain, and also to the fact that it was not successful when applied to internally-fired boilers.

A large number of stokers were subsequently patented in Great Britain, designed to work on the "coking" principle, viz., to receive the coal at the front of the furnace and discharge the burnt-out residue at the back. In the majority of these the grate bars extended longitudinally from front to back, instead of crosswise as in the Jukes stoker, and the fuel was advanced by a slow reciprocating movement of the bars, communicated by means of cams or cranks on a transverse shaft on the front end of the boiler,—all being modifications of Brunton's system. Among these were a stoker designed by Normand in 1856; one by Wilson and Smith in 1863; one by Vicars and Smith in 1867 and 1868; and Knapp's, Mc-

Dougall's, and the Holroyd-Smith stokers, patented subsequent to 1868.

The last-named (Figs. 11 and 12) was patented in 1878, and, though a "coking stoker," differed from the others in having, instead of movable horizontal grate-bars, three longitudinal troughs, pushed up through the centre of the fire by means of a movable section of the grate, working like a plunger. A number of modifications of this idea were



LONGITUDINAL SECTION. FRONT ELEVATION.

FIG. 2—THE VICARS STOKER, MADE BY MESSRS. T. & T. VICARS., EARLESTOWN, LANCASHIRE, ENGLAND.

placed at right angles with a hopper across the boiler front, from which they received the coal, single bars being placed in alternation with the troughs. The fuel was moved upwards and towards the back of the furnace by double-threaded screws, one in each longitudinal trough. These screws tapered from 5 to 2½ inches in diameter, and revolved at varying speeds, from two revolutions per minute upwards, as required.

In 1866 and 1869 Howarth and Horsfall invented a coking stoker with hollow fire-bars, supplied with water from the boiler. The bars were stationary, and the coal was carried along by a saw worked by an eccentric; but frequent leakage of the hollow bars led to its failure, although it was successful when in working order.

Somewhat similar in its operation to the Holroyd-Smith was an under-feed stoker, patented by James Frisbie, in 1844, although in construction it was more like Dowson's stoker, patented in 1816. In Frisbie's stoker the coal was tried, and about thirty patents taken out, but all were abandoned on account of inherent difficulties.

The Hopcraft mechanical stoker, shown in Fig. 1, and patented in 1889 by Lewis Hopcraft, of London, is another modification of the Holroyd-Smith under-feed stoker. The grate is circular, placed at an angle of about 30 degrees from the horizontal, the grate bars being arranged in concentric circles and carried on radial arms having a sinuous upper surface, arranged to be revolved by means of a chain attachment. The coal is supplied from a hopper on the boiler front to a screw conveyor constructed in sections, fitted together by universal joints working on a central rod bent to the required shape, and which delivers it into the furnace through an opening in the centre of the inclined grate. An evident obstacle to its continued successful operation is its complicated construction and the inaccessibility of the wearing parts. It was patented in the United States in 1891.

Of the "coking stokers" of the Brunton type, the most recent construction is shown in the Vicars mechanical stoker, represented in Fig. 2. This was first patented in 1879, and the improved form in 1889.

Between the years 1841 and 1875 many patents were taken out in Great Britain on modifications of Stanley's "sprinkler stoker," by E. Henderson, W. and J. Galloway, Robert Newton, Church, Rey, Hodgkinson, Dilwyn Smith, Barker, Whittaker and Newton, Proctor, and Bennis. The last two mentioned were patented in 1875. These all differed principally in the method of delivering or sprinkling the coal on the grate, and the manner of moving the grate bars, when made movable. The Hodgkinson stoker crushes and distributes the coal over the fire by means of a ribbed roller in the bottom of a hopper on the boiler front. This roller, running at a high rate of speed,—800 revolutions and upwards per minute,—is intended to scatter the coal in a fine shower over the fire. The mechanical objections to a shaft running at such a high speed in the dust of a fire-room and attached to a boiler front which is liable to warp out of place, scarcely require emphasis. They are self-evident.

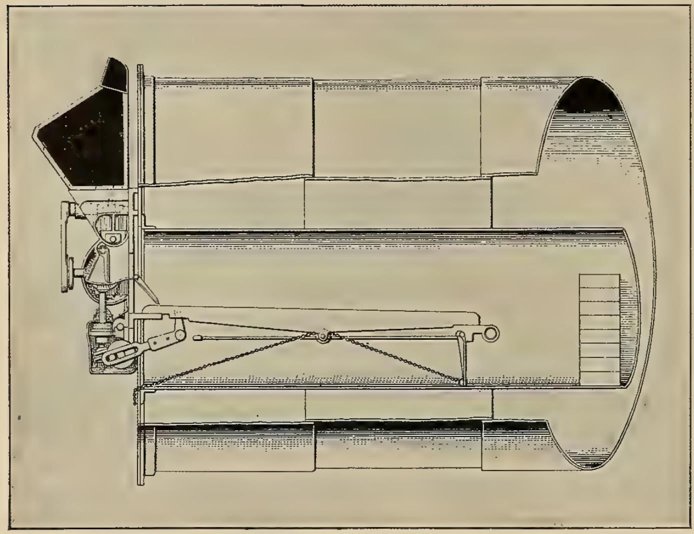


FIG. 3—MECHANICAL STOKER MADE BY J. PROCTOR, BURNLEY, ENGLAND.

The Proctor and Bennis stokers use shovels actuated by springs and cams, so arranged as to give different velocities to the successive strokes or throws of the shovel. The purpose of this variation in the throw of the shovel is to distribute the coal uniformly over the fire. The grate bars in the Bennis and Henderson stokers have a longitudinal reciprocating motion, for the purpose of breaking up the clinker and carrying it forward to the bridge. The Proctor stoker accomplishes the same result in a measure by an up-and-down movement of the front ends of each alternate grate bar. The remainder of the "sprinkler stokers" just mentioned have stationary grate bars and distribute the coal on the grate by rapidly revolving fans or beaters, attached to a horizontal or a vertical shaft, placed at the bottom of a hopper on the boiler front. British mechanical stokers are of two

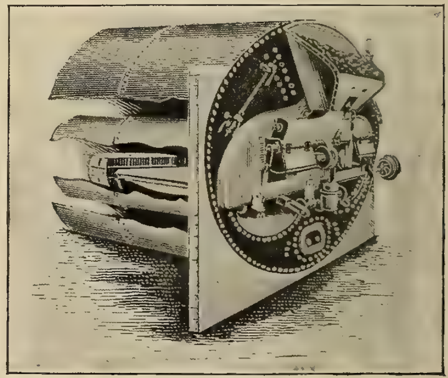
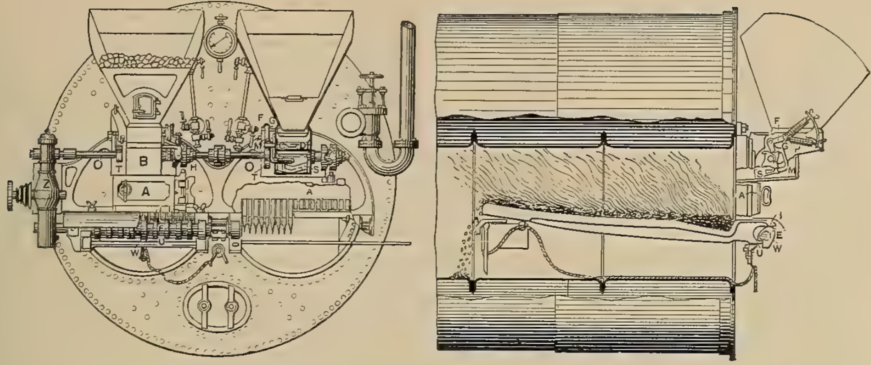


FIG. 4—SECTIONAL PERSPECTIVE OF THE PROCTOR STOKER.



FRONT ELEVATION. LONGITUDINAL SECTION.

FIG. 5—THE BENNIS STOKER, MADE BY MESSRS. E. BENNIS & CO., LTD., BOLTON, ENGLAND.

distinct types, designated respectively as "coking" and "sprinkler" stokers, both having a hopper attached to the boiler front for receiving the coal and delivering it to the feeding mechanism. In the coking stoker the fuel is fed slowly on to the dead plate, movable bars being provided for carrying it forward at a rate intended to be proportionate to that of the combustion required. In the sprinkler stoker the fuel is more or less evenly distributed on the grate by fans, beaters, or shovels, and with or without movable grate bars. In both systems of feeding, it is claimed that with moving bars, the fuel is so entirely burnt out by the time it reaches the bridge-end of the grate that there is nothing left but ash and clinker, which drop into the space provided for them, and from which they are removed through the ash-pit.

It may be of interest to describe briefly one of the most successful of each type of British stokers, selecting for the purpose the Vicars coking-stoker (Fig. 2), and the Bennis sprinkler-stoker (Fig. 5), as not only do they represent the latest improvements in each type, but also in the number installed they are each far ahead of other stokers of their class.

The Vicars stoker is shown applied to a Lancashire boiler of usual construction. Small bituminous coal is placed in the fuel hopper, from which it falls by gravity into four boxes,—two for each furance,—located underneath the hopper, and is gradually fed into the furnaces by alternately reciprocating plungers. Each plunger receives its motion from a bell-crank lever connected with an eccentric and strap upon the cam-shaft.

The grate bars have a peculiar recip-

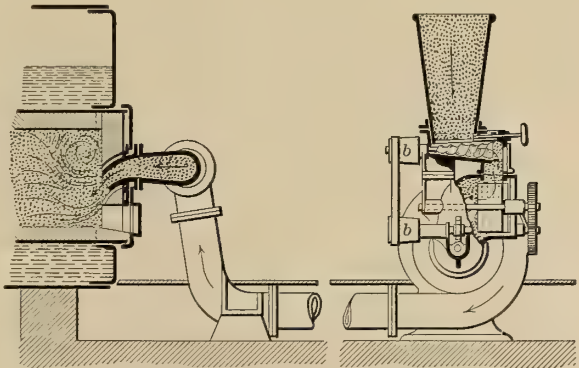


FIG. 6—A STOKER FOR FIRING COAL DUST, DEVISED BY F. DE CAMP, BERLIN, GERMANY.

rocating motion, being moved slowly forward simultaneously, but returning in two sections by alternate bars. The maximum length of the stroke is four inches. By this means the burning mass is gradually but slowly carried forward. The clinker and ash, together with any unconsumed fuel, fall over the

back ends of the bars, into the flue, forming a bank which acts as a bridge to close the back end of the ash-pit, and on which the combustion of the partially burned coal is completed.

The clinker and ash are drawn out from underneath the grate at intervals varying from three to twenty-four hours, according to the quality and quantity of coal consumed, sufficient being left at the back to prevent cold air passing into the combustion chamber except through the bed of burning coal on the grate. A small quantity of steam is allowed to blow from a perforated pipe upon the back ends of the grate bars, for the purpose of keeping them and the bearers cool.

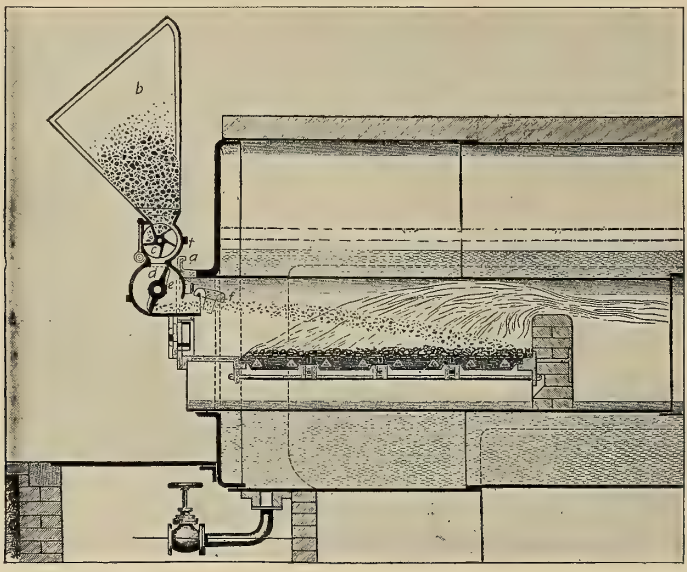


FIG. 7—A GERMAN MECHANICAL STOKER, MADE BY "DIE SÄCHSISCHE MACHINENFABRIK ZU CHEMNITZ." GERMANY.

The supply of fuel and the travel of the bars are regulated by a simple mechanical arrangement, so that any desired quantity of fuel is supplied and the motion of the bars is proportioned to the rate of combustion. Smoke is entirely prevented when the feeding of fuel is properly regulated, inasmuch as the coal is partially coked before passing on to the bars, and the gases given off in the coking process at the front end of the grate are consumed before they pass from the combustion chamber.

The Bennis stoker (Fig. 5) also is shown applied to an ordinary Lancashire boiler. Two hoppers for receiving the coal are attached to the front end of the boiler, forming two independent stokers, —one to each furnace. Under the hopper is placed the stoking apparatus, consisting of a cast-iron box, *B*, with a shelf, *C*, inside, on which a pusher-plate, *D*, slides, and below the shelf, resting on the bottom of the box, *B*, is the throwing apparatus, consisting of a *V*-shaped shovel, *S*, which is hinged to the shovel-arm, *M*.

On the side of the shovel-arm is a projection with which the tappet, *T*, engages so as to draw back the shovel-arm and shovel against the pressure of the throwing-spring, *P*. While the shovel is being prawn back, a measured quantity of coal is dropped in front of it by the pusher-plate, *D*, which slides back and forward on the shelf, *C*. The pusher-plate receives its motion from a scroll-cam, *H*, which is made in two parts, so that it can be opened or closed for the purpose of regulating the stroke of the pusher-plate and the amount of fuel delivered in front of the shovel, *S*. When the tappet releases the arm, *M*, it darts forward and the shovel, *S*, strikes the heap of fuel with more or less force, according to the distance it has been drawn back, scattering it over the fire.

The tappet is made with four different-sized lifts, so that in each revolution four throws of varying force will be

given. These throws are so adjusted that the first delivers the fuel on the front part of the bars near the fire-door; while the next charge is thrown nearly to the rear end of the bars, and is scattered across the fire over a space about two feet in width; the third throw delivers the coal just beyond the first, and the fourth just beyond that. The object of this peculiar arrangement is to give time for consumption of the suddenly liberated hydro-carbons before a fresh charge of fuel is added, thus preventing smoke, and producing perfect combustion.

The grate bars, which are inclined towards the front, have a depression about three inches deep just inside the boiler front, for the purpose of assisting the forward movement of the bed of burning fuel. This movement is effected by the whole of the bars being pushed forward a distance of 1½ inch by means of cams, which are set at slightly varying points on the shaft, so that the bars are brought back of the front in series, only one in eight returning at the same time, thus leaving the clinker and fire 1½ inch further forward for each revolution of the cam-shaft. This movement of the grate bars is similar to that patented by Bodmer in 1843, but the mechanism for returning the bars to the front is simpler and more effective than that used by Bodmer. Steam is introduced underneath and in front of the dead-plates by means of a perforated pipe, the effect being to prevent the adhesion of clinker to the bars, and also to act as an aid to combustion.

Proctor's stoker (Figs. 3 and 4) is very much like the Bennis stoker in appearance and operation, the principal difference being in the manner of moving the bars, the form of the throwing shovel, and method of communicating motion to it. It is second to the Bennis stoker only in the number of stokers of this type installed in Great Britain.

In 1879 James Newton invented a stoker by which fine coal was propelled into the furnace by a blast of heated air, delivered at intervals, by means of a fan.

Recently considerable attention has been given, both in the United States and Europe, to the problem of burning pulverised coal, and some degree of success has been attained. Fig. 6 shows a coal dust stoker patented in 1895 by F. De Camp, of Berlin, Germany, which, it is claimed, has been in successful operation for eighteen months or more. The coal is ground in a mill and carried to the hopper of the stoker by a travelling conveyor, from which it is delivered into the furnace by a fan blast. The quantity of coal dust as well as the quantity of air blown into the furnace is regulated by slides. The advantages claimed for the apparatus are, that it is

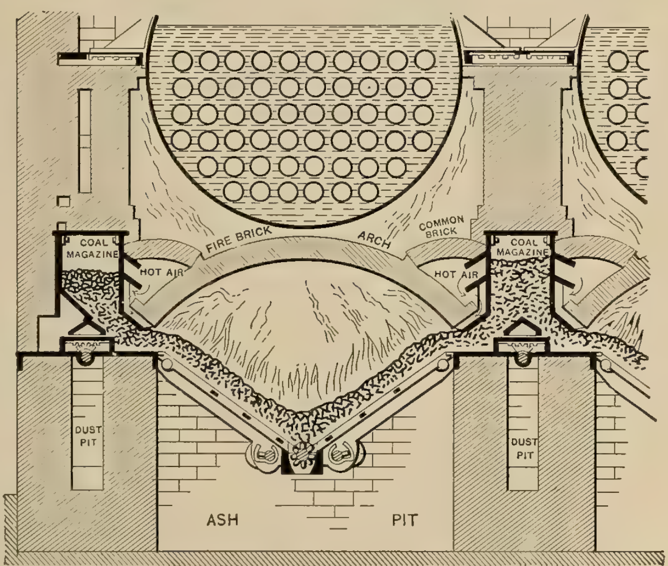


FIG. 8—A CROSS-SECTION OF MURPHY'S SMOKELESS FURNACE, MADE BY THE MURPHY IRON WORKS, DETROIT, MICH., U. S. A.

an automatic stoker and forced draft system combined, and that the combustion is complete and smokeless.

The objections are, the cost of power for grinding the coal into a fine powder and for driving the fan, together with

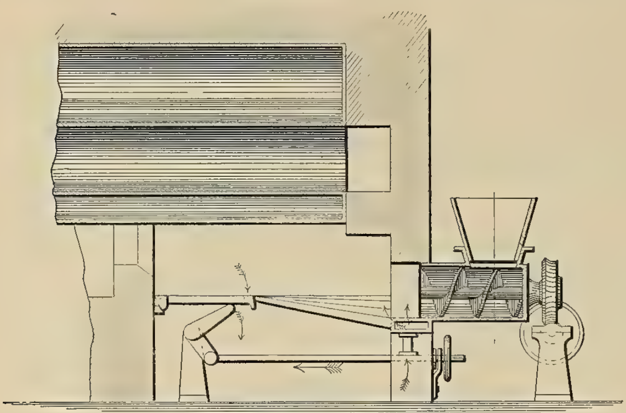


FIG. 9—SECTIONAL ELEVATION OF THE STOKER DESIGNED BY A. L. SCHULTZ.

the extra labour required to keep the flues clean, on account of the large accumulation of ash and partially burned coal dust which is carried over by the blast.

In Germany a number of mechanical stokers have been patented since the year 1850; but, as a rule, they are merely modifications of the British stokers already described. This fact is well illustrated by Fig. 7, which represents one of the latest German stokers, patented in 1895, and now being placed on the market. The construction, as is evident from the cut, is but slightly changed from that of the majority of "sprinkler" stokers patented in Great Britain between 1841 and 1889; but it lacks the advantages which they possess, of an adjustable feed, movable grate bars, and an automatic discharge of the ash and clinker into the ash-pit. With this stoker the fire is sliced and cleaned by hand and the ashes and clinkers are removed through the front door just as in the case of the ordinary hand-fired furnace.

While it must be acknowledged that the mechanical stokers already described were a great improvement over hand-firing, still, from the standpoint of the author, they possess faults, aside from their lack of adaptability to the fuel and the types of boilers, for example, most used in the United States. These faults pertain to the feeding or stoking mechanism, and to the grate bar construction, and are, briefly, as follows:—

First—The feeding mechanism is either of so complicated a nature, or runs at so high rate of speed, as easily to get out of order. In the case of shovel-stokers, it is dependent upon springs, which, in time, must lose their tension, and the nice adjustment of variable throw of the shovel fails, and, as a result, the fuel is unequally distributed over the fire. Even when the springs are in perfect condition, unless they are adjusted with great care and

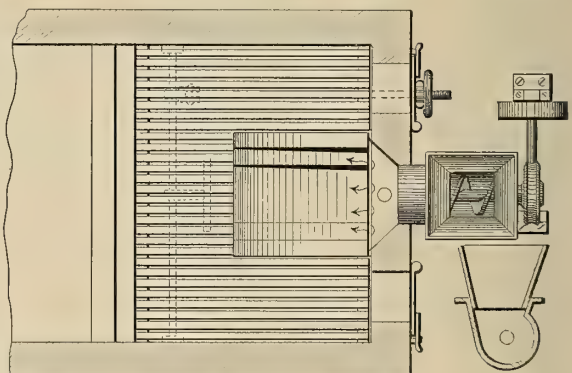


FIG. 10—PLAN OF THE A. L. SCHULTZ STOKER.

accuracy, the lumps will fall in one place and the fine dust in another, producing a fire of uneven thickness.

In the case of stokers which deliver the coal on the grate by means of rapidly-revolving fans, beaters, or rolls, there is the more serious fault of the great wear caused by running at such high speeds in coal dust and ashes, and where the high temperature of bearings attached to the boiler front often precludes lubrication. Secondly, the continuous rain of fine coal falling into the air holes in the fire, chokes and impedes the draft, while the larger and heavier pieces pile up at the front end of the grate. Thirdly, the fan-like draft drives large quantities of ashes and coal dust over the bridge, impeding the flow of the hot gases through or among the tubes, and reducing the efficiency of the boiler.

Second.—The grate construction is such that the bars are often inaccessible, either for examining the condition of the fire, or slicing it when necessary, or for renewing burnt or worn-out parts. The bars being horizontal, the fire cannot be stirred from beneath, and when once in place, the air spaces in the grate cannot be changed according as the coal is fine or coarse, to prevent loss by sifting, or to regulate the air supply according to the grade of coal burned.

The actuating mechanism is frequently complicated and expensive to keep in repair, especially where exposed to the heat or moving in the fire,—a serious objection when the nature of the service required and the character of the labour usually employed in the fire-room is taken into consideration. The simplest and best-designed stoker that inventive genius can produce wlli receive hard usage in the hands of the average fireman.

The first distinctively American mechanical stoker was patented in 1879, by Thomas Murphy, of Detroit, Mich., under the name of the Murphy patent furnace. This stoker, which he further improved in 1881, by the addition of a small engine for operating it, is worthy of note, both on account of priority,

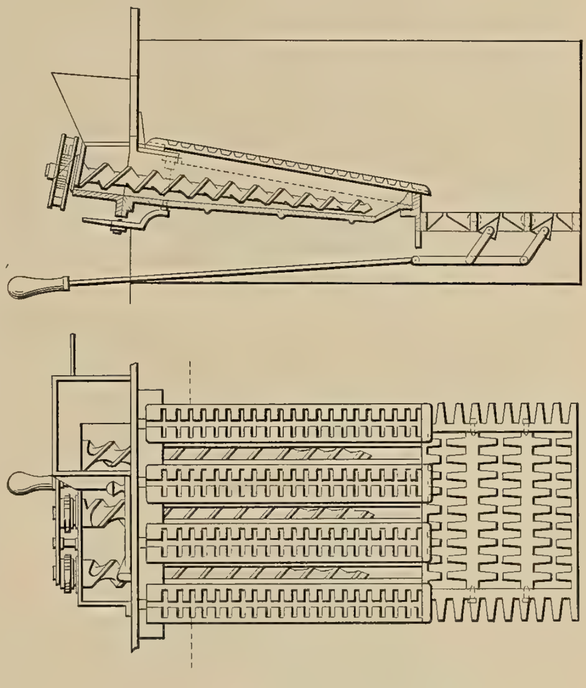


FIG. 11—THE M. HOLROYD SMITH STOKER.

and on account of being a radical departure from the British types of stokers.

The Murphy, like all American stokers that burn bituminous coal, is a "coking stoker." As will be seen

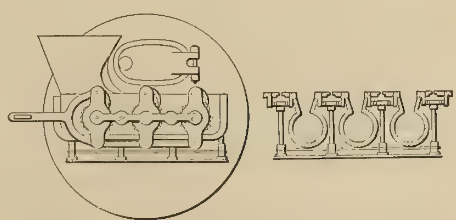


FIG 12—A DETAIL OF THE HOLROYD-SMITH STOKER.

from Fig. 8 it consists of two coal magazines, placed in the side walls of the boiler furnace, and extending

back from the boiler front 6 or 7 feet. In the bottoms of these magazines are rectangular iron boxes, which are moved from side to side by means of a rack and pinion, for the purpose of pushing the coal upon the grates, which incline at an angle of about 35 degrees from the inner edge of the coal magazines, forming a *V*-shaped receptacle for the burning coal. The grates are composed of narrow, parallel bars, so arranged that each alternate bar is lifted about an inch at its lower end by a rod which engages with it somewhat after the manner of a cam-shaft. At the bottom of the *V*, between the ends of the grate bars, is placed a cast iron toothed bar, arranged to be turned by a crank, for the purpose of grinding the clinker. Large pieces of clinker which the teeth will not reach are usually hauled out through a door opposite the middle of the furnace and quenched with water. This door is also used as a means of access to the grates for slicing and stirring the fire when necessary.

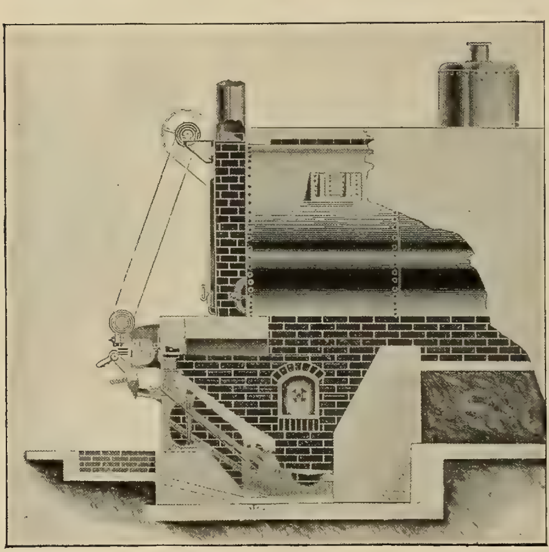


FIG. 13—SECTION OF BOILER SETTING WITH A BRIGHTMAN STOKER, MADE BY THE BRIGHTMAN FURNACE CO., CLEVELAND, O., U. S. A.

Over the *V*-shaped receptacle is sprung a fire brick arch, extending back about one-third the length of the boiler, each foot resting upon ribbed cast iron skew-back plates. Immediately above the skew-back plates secondary common brick arches are placed, forming hot air chambers which are supplied by means of air passages in the walls. The heated air is drawn down through the spaces between the ribs on the skew-back plates, and, mingling with the gases from the coking coal, a practically smokeless combustion is obtained, except when it is necessary to open the door for slicing or stirring the fire. This stoker has made a good record for smokelessness and economy, and a large number have been installed, although it is somewhat handicapped by high first cost and a construction which makes repairs quite expensive. It operates most satisfactorily with a bituminous coking-coal.

During the years 1878 and 1879 a number of British and other stokers which had been patented in Europe were also patented in the United States. Among these were Holroyd-Smith's, Vicars', Bennis' and others, as well as one patented, in 1878, by Aug. L. Schultz, of Saxony (Figs. 9 and 10). The latter supplied the coal from a hopper on the boiler front to a trough which was partly below the level of the grate, from which it was forced into the furnace by means of a large screw driven by a worm and gear. The fuel was pushed up a slight incline and fell over on either side upon the horizontal grate. A section of this grate, next to the bridge, was dropped, when desired, to discharge the ash and clinker into the ash pit. An air blast was introduced through tuyere-shaped openings in the trough near the top, which, mingling with the coal as it entered, produced intense smokeless combustion.

In 1885 the Brightman mechanical stoker was patented by J. A. Brightman, of Cleveland, Ohio, and in the same year the Roney mechanical stoker

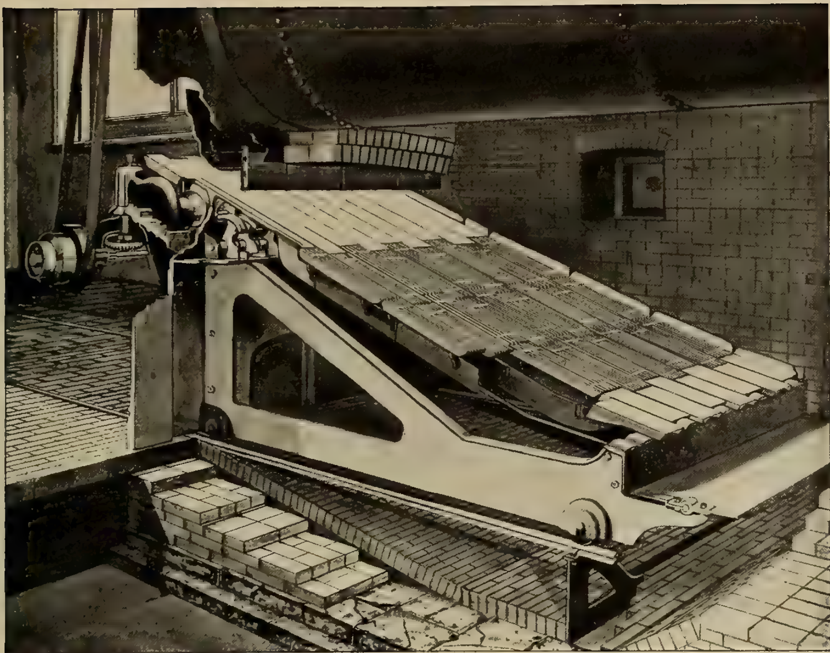


FIG. 14—THE VULCAN STOKER, MADE BY THE KANSAS CITY SPECIALTY CO , KANSAS CITY, MO., U. S. A.

was brought out by the author of this article.

The Brightman stoker is shown in Fig. 13, applied to a horizontal return tubular boiler. It consists of a hopper or coal magazine placed transversely across the front, from which the fuel is fed into the furnace by a plunger-pusher, which slides back and forth upon a cast iron feed-table forming the bottom of the hopper and extending into the furnace over the upper end of the grate. This is composed of parallel bars inclined at an angle of 38 degrees, and provided with projecting over-lapping lugs, each alternate bar having a reciprocating swinging motion for the purpose of moving the fuel down the grate.

This motion can be supplemented, when necessary, by using a poker through an opening provided for that purpose in the hopper. The motion of the pusher and of the grates is regulated by a simple device which permits of a sufficiently wide range to produce very satisfactory results. The ash and clinker accumulate on the horizontal portion of the grate, and are drawn out with a hoe through an opening, made by letting down the vertical portion which is hinged at the bottom, the larger masses being first broken up with a slice bar.

A number of improvements were patented in 1889 by H. H. Campbell, of Cleveland, Ohio. They pertained principally to the grate bars, which he made with removable tops to facilitate renewing the burnt parts. This stoker burns bituminous coal, both "run of mine" and "slack," with good economy and freedom from smoke, except when forced. While it has an advantage over the Murphy stoker in being of simpler construction, still the long fire brick arch enables the Murphy device to maintain a more intense heat in the furnace and more nearly smokeless combustion.

The next mechanical stoker patented in the United States,—March, 1889,—was the Vulcan, invented by M. H. Moskovitz, of Kansas City, Mo. As will be seen from Fig. 14, it consists of an inclined set of stepped "zig-zag" bars which project through the boiler

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front sufficiently to form the bottom of the hopper which receives the coal. The lower end rests on balls, while the upper ends engage by means of *U* bearings with a crank-shaft, from which

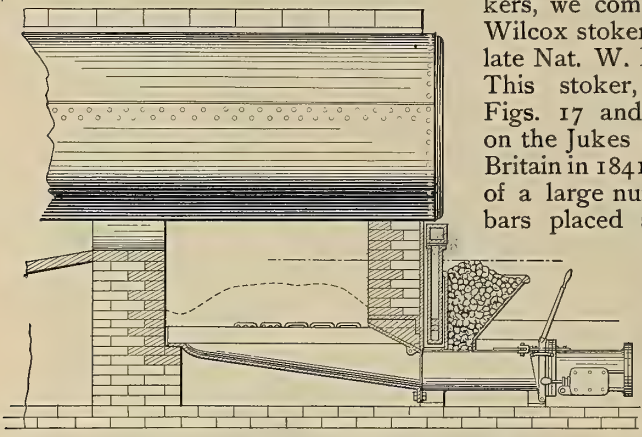


FIG. 15—THE JONES UNDER FEED STOKER, MADE BY MESSRS. FRASER & CHALMERS, LONDON AND CHICAGO.

they receive a reciprocating motion. The frame supporting the grate is mounted on wheels resting on tracks, which permit its being drawn out when desired.

The Jones under-feed stoker (Figs. 15 and 16) was patented in 1896 by E. W. Jones, of Portland, Oregon. It belongs to the class of which Dowson's stoker, patented in 1816, is the first example, followed by Frisbie, Holroyd-Smith and Hopcraft, in Great Britain, and Schultz, in Germany. In all these stokers the fresh coal is pushed up through the bed of burning fuel by various devices. In the Jones stoker, the coal is forced in by a steam ram, operated by a hand lever connected to a valve, by means of which the charges of fuel can be delivered as required. Air at four ounces pressure is forced through the tuyere blocks, and up through the heap of burning fuel, in the same manner as in the Schultz stoker, patented in 1878, and, mingling with the gases from the coking coal, produces an intense and rapid combustion. Owing to the large excess of air delivered at high pressure, and its thorough mingling with the gases, a practically smokeless combustion is obtained. This stoker has been principally used with low grade Western American bituminous slack, which it handles quite successfully.

Continuing, chronologically, the examination of American mechanical stokers, we come next to the Babcock & Wilcox stoker, patented in 1890 by the late Nat. W. Pratt, of Brooklyn, N. Y. This stoker, as will be seen from Figs. 17 and 18, is an improvement on the Jukes stoker, patented in Great Britain in 1841. The grate is composed of a large number of short corrugated bars placed side by side, forming a broad endless belt which slowly travels inward at the rate of about 2½ inches per minute, in the same manner as the Jukes grate already described. Its construction differs, however, in that the bars in the Jukes grate were placed crosswise the furnace. The form of the hopper is also quite different, and the method of moving the grate and feeding the coal is an improvement over the Jukes. These features will easily be understood from the illustrations. A roller in the bottom of the hopper, for breaking the larger lumps, was a feature

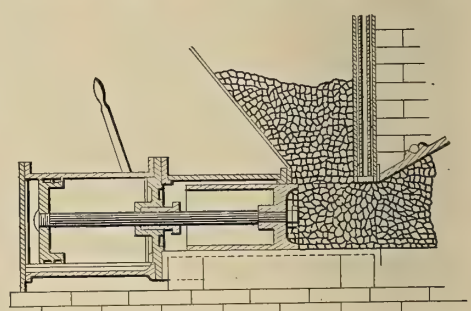


FIG. 16—THE RAM OF THE JONES STOKER.

of the earlier construction, but it is now usually omitted.

As will be noted, the grate is mounted on a truck and can be removed from the furnace for inspection or repairs. In this it is similar to the Vulcan stoker, already mentioned. The present stoker is designed for burning bituminous coal

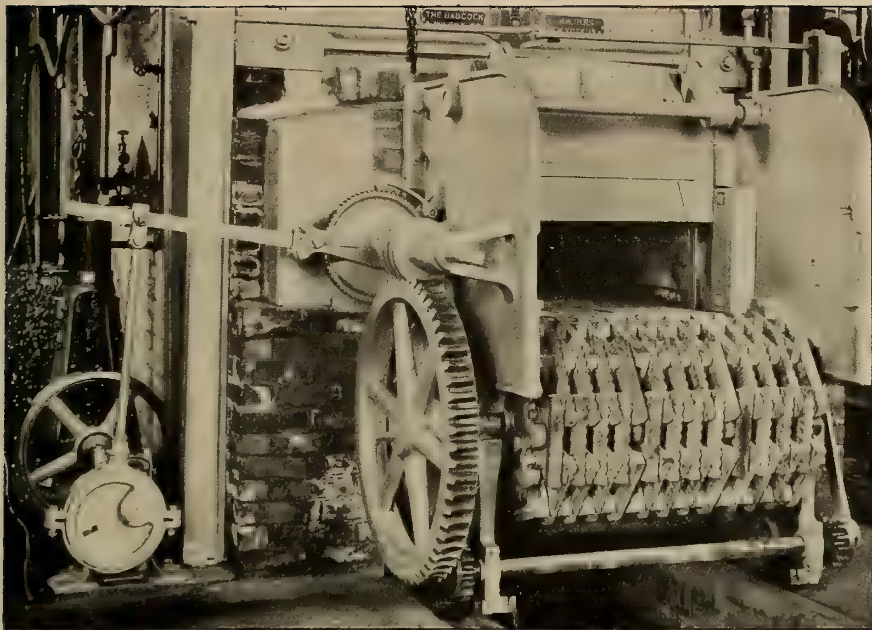


FIG. 17—THE STOKER MADE BY THE BABCOCK & WILCOX CO., NEW YORK.

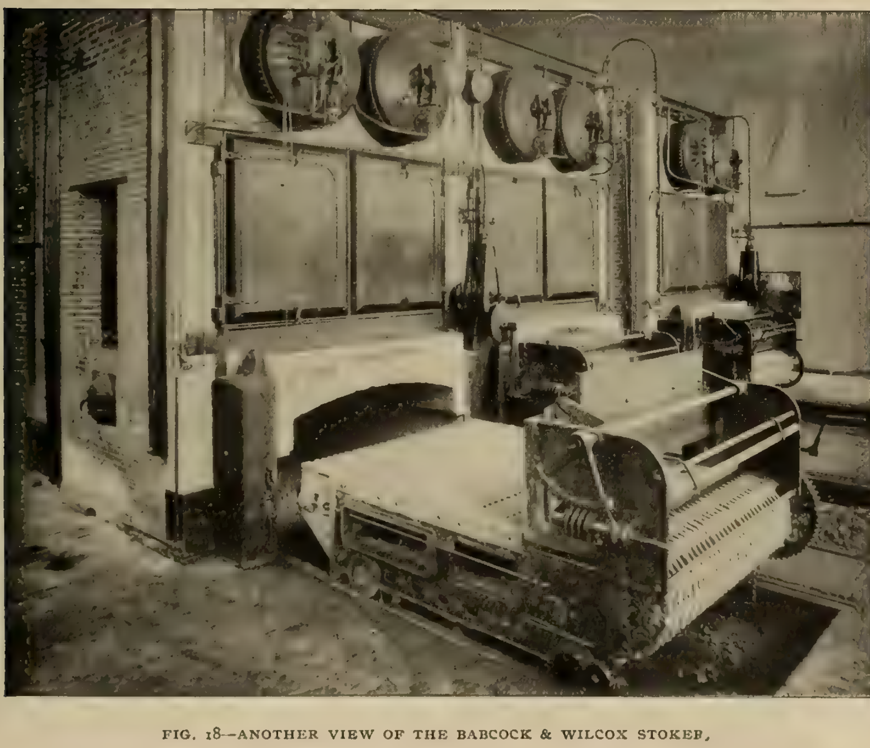


FIG. 18—ANOTHER VIEW OF THE BABCOCK & WILCOX STOKER.

only, which it handles very satisfactorily; a coking coal, however, burns most successfully because there is less sifting of fine coal through the moving grate. It

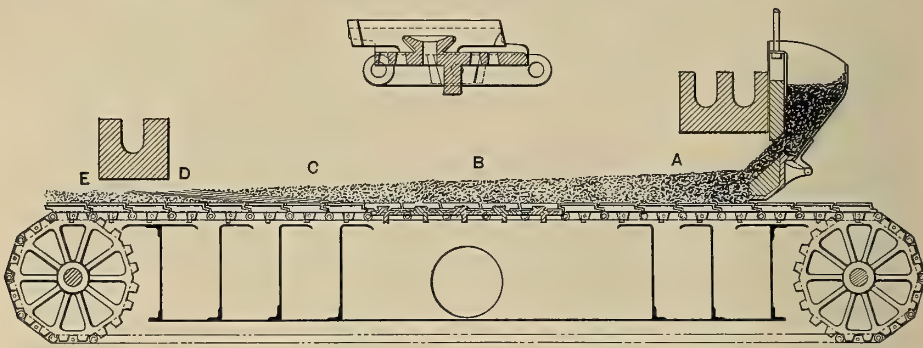


FIG. 19—THE COXE AUTOMATIC STOKER, MADE BY MESSRS. COXE BROS. & CO., DRIFTON, PA., U. S. A.

has shown good results in economy and smokelessness. Recent tests show that it quickly responds to fluctuating boiler demands, when the draft is good, but it requires a strong draft, whether natural, induced, or forced.

It is interesting to refer here to a revolving-grate stoker, also patented by Mr. Pratt in the years 1890 and 1892. It consisted of a circular, horizontal rotary grate, made up of a series of radially-pivoted sectoral sections, which were so balanced that they dumped automatically by the movement of the

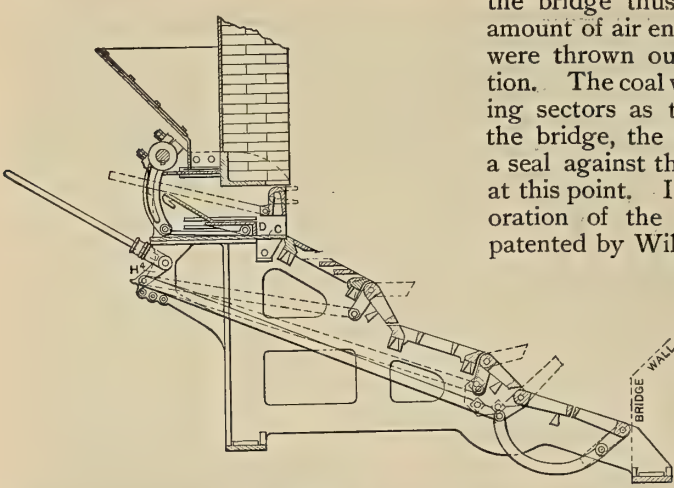


FIG. 20—THE MEISSNER STOKER, MADE BY THE MEISSNER ENGINEERING CO., PITTSBURGH, PA., U. S. A.

grate, and thus each discharged its load of ash and clinker successively when a given point was reached. The coal was supplied from a hopper placed above the dome-like arch covering the furnace, by a combined spiral crusher and feeder, which discharged the fine fuel near the outer portion of the revolving grate. A bridge extended from a central pier to the covering arch, and under it the sectors passed while being dumped, the bridge thus preventing an undue amount of air entering when the sectors were thrown out of their normal position. The coal was fed onto the revolving sectors as they passed from under the bridge, the fresh fuel thus forming a seal against the admission of cold air at this point. It was an ingenious elaboration of the crude revolving grate patented by William Brunton, of Birmingham, England, in 1819. Owing to its complicated character and expensive construction, however, only a few of these stokers were built.

The late Eckley B. Coxe, of Drifton, Pa., was greatly interested, both as an engineer and as an extensive coal miner, in the waste fuel problem of the anthracite coal fields. It was quite natural, therefore, that having been appointed a member of the commission created by the Legislature of Pennsylvania for the purpose of investigating the " Waste of

Coal Mining, with the View of Utilising the Waste," he should have commenced, in 1890, a series of experiments in burning small anthracite coal. As a result of these experiments, in which he was ably assisted by Mr. John R. Wagner, he brought out a stoker, which was patented in 1893. Subsequently, in 1894, he took out thirty-one patents on various modifications and improvements. A number of patents for devices used in connection with the Coxe stoker were taken out by F. H. Richards, of Hartford, Conn., and assigned by him to Eckley B. Coxe.

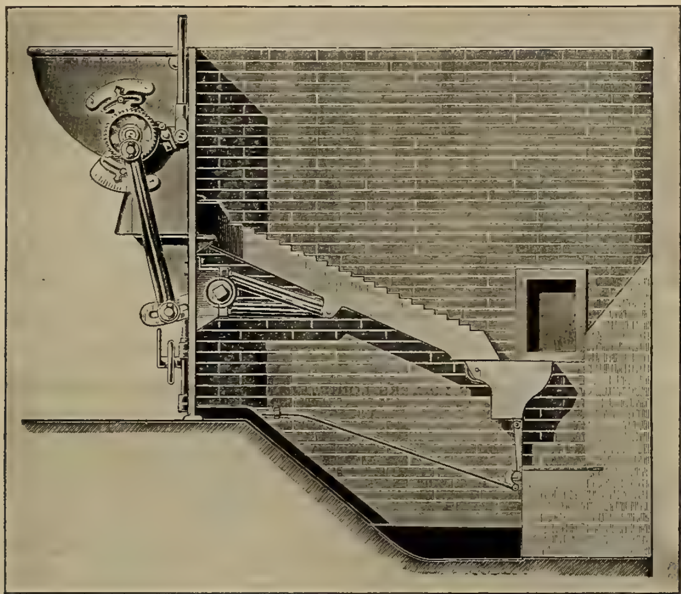


FIG. 21—THE BOX STOKER, MADE BY MESSRS. ALFRED BOX & CO., PHILADELPHIA.

The Coxe stoker, shown in longitudinal section (Fig. 19), belongs to the class of travelling chain-gate stokers. It consists of a travelling grate, formed of horizontal perforated plates bolted to *T*-shaped ribs, which are placed crosswise in the furnace, and connected at their ends to bar-link chains running over sprocket wheels. Under the grate are a number of chambers made of sheet iron, which are closed on all sides except the top. Fan blast is used which discharges the air into the large air chamber. The partitions are covered with plates so placed that the air cannot pass from one chamber to the next except by leakage along the bar. By this arrangement it is intended that a graduated pressure shall be maintained in the air chambers,—as, for example, one inch pressure in the large chambers, ¾ inch in the next to the left, ½ inch in the next, and ¼ inch in the last.

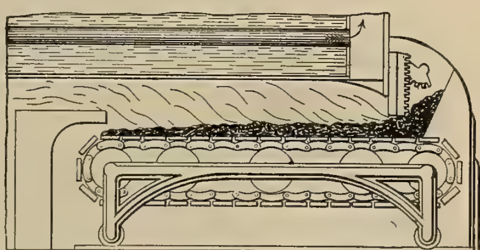


FIG. 22—STOKER MADE BY THE PLAYFORD STOKER CO., CLEVELAND, O., U. S. A.

The purpose of this graduated pressure, as Mr. Coxe explained in a paper read before the American Institute of Mechanical Engineers in 1893, is to provide a sufficient supply of air to

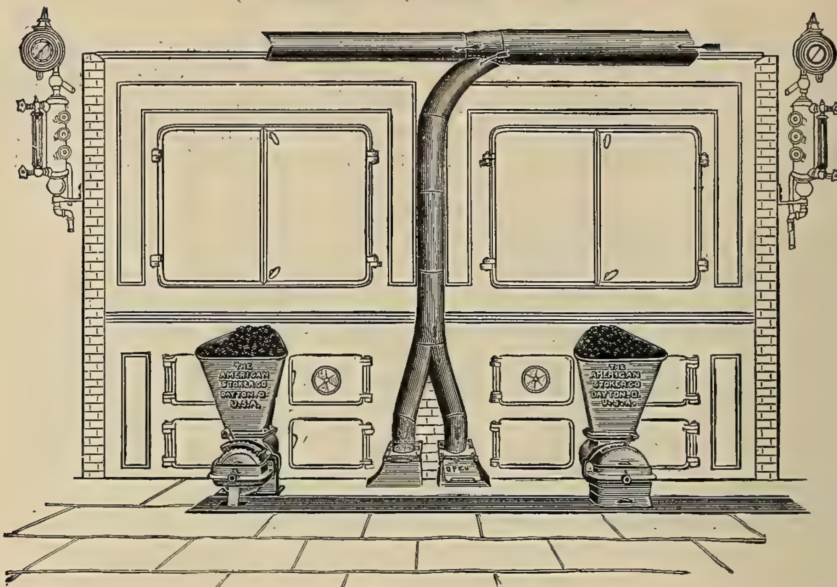


FIG. 23—FRONT VIEW OF A SET OF BOILERS EQUIPPED WITH AMERICAN UNDER-FEED STOKERS.

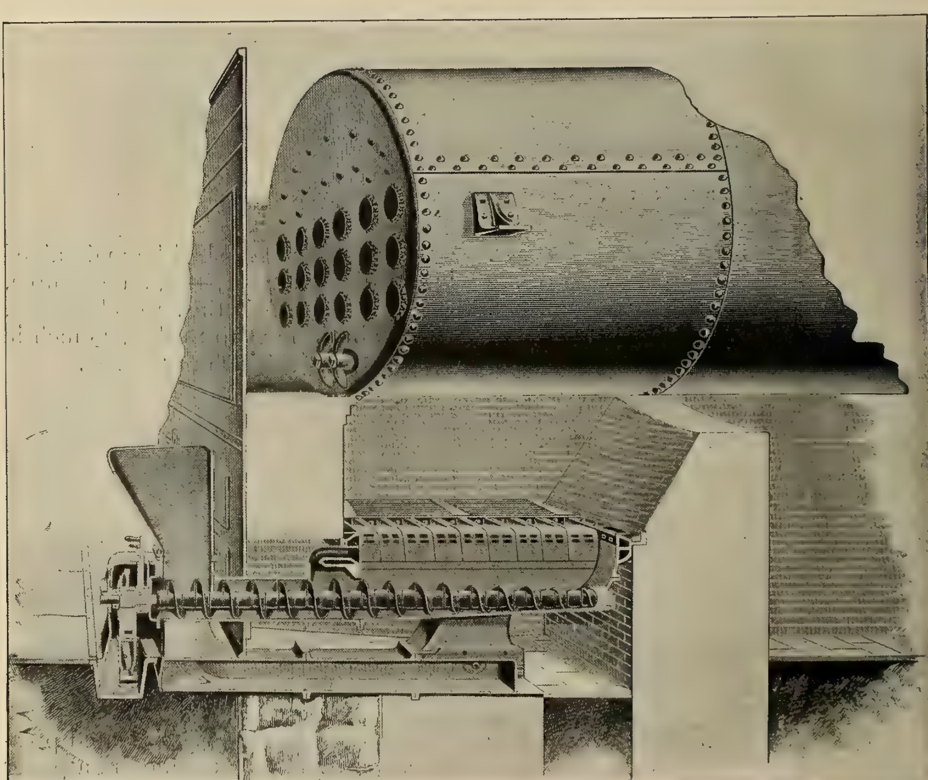


FIG. 24—THE AMERICAN UNDER-FEED STOKER, MADE BY THE AMERICAN STOKER CO., DAYTON, OHIO, U. S. A.

ignite the coal when it arrives on the grate, but not too strong a pressure to impede its ignition. As the coal enters the furnace from the hopper, it passes over an inclined fire-clay tile, and gradually becomes heated, so that it is incandescent soon after reaching the grate, and is ignited by the air blast. As the thoroughly ignited coal passes slowly over the second compartment, it burns briskly, and then, passing over the third compartment where the air pressure is less and better suited to the combustion of the thinner layer of partially consumed coal, the bed continues to diminish in carbon, and to be subjected to less blast, until finally the hot ashes are cooled off, before being dumped, by a very gentle current of air, which is heated and mingles with the carbonic oxide produced in the zone of intense combustion *B*, and converts it into carbon dioxide, the object being to subject the coal, as soon as it arrives at the grate, to a pressure of blast which is the proper one to ignite it, then burn it with a blast as strong as will produce good combustion, and, as the carbon is eliminated and the thickness of the bed becomes less, to diminish the blast to correspond to these conditions. The mass of coal, moving at the slow rate of 3½ to 5 feet per hour, remains at all times in practically the same condition in which it was placed on the grate, except as altered by combustion.

This stoker is interesting on account of the care and study spent in developing this method of burning anthracite coal by a graduated air blast. It requires, however, careful and intelligent handling in order to realise the benefits of this system. It is not adapted for burning bituminous coal.

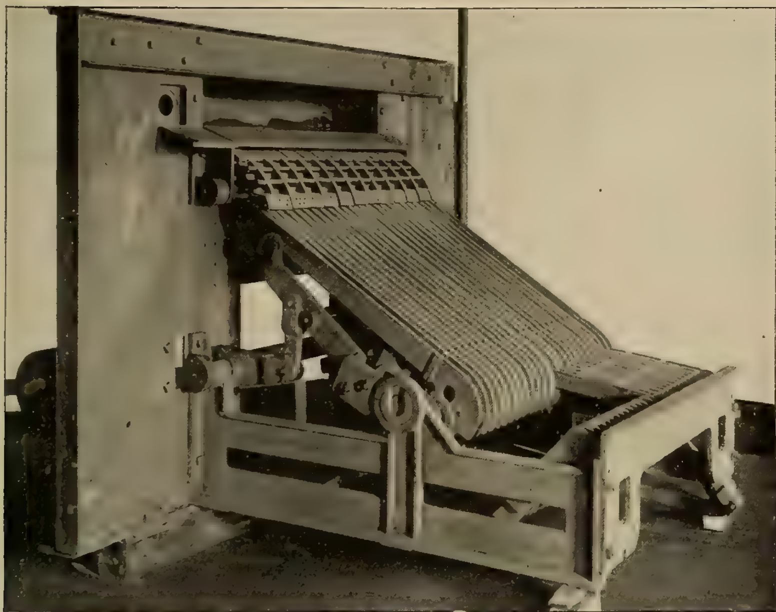


FIG. 25—STOKER MADE BY THE BUCKEYE ENGINE CO., SALEM, O., U. S. A.

The Meissner stoker was patented in 1894 by Julius H. Meissner, of Pittsburgh, Pa. In design it is a modification of what is known as the "German stepped-grate." Fig. 20, which is a longitudinal sectional view, clearly shows the construction. It comprises a hopper, attached to the front, and underneath it is a plate on which a reciprocating pusher slides, and a grate composed of stationary and movable sections. The upper one-third of the

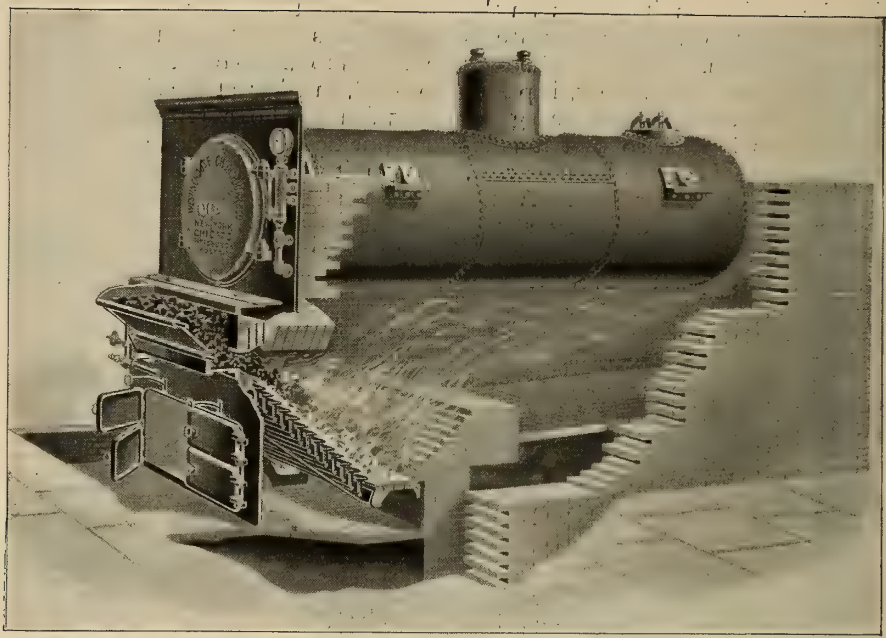


FIG. 26—THE RONEY MECHANICAL STOKER, MADE BY MESSRS. WESTINGHOUSE, CHURCH, KERR & CO., NEW YORK.

grate is in the form of fixed overlapping steps, while the middle portion, which is also stationary, is composed of narrow longitudinal bars. The lower one-third, as well as a narrow section between the upper and middle stationary grates, is arranged to tilt at right angles with the plane of the grate and thus break up the coked fuel and dump the ash and clinker.

This tilting of a portion of the grate also permits using a slice-bar to break up the bed of coal and push it down on to the damp grate. This is quite necessary, since the angle of inclination is such that the coal will not move down the grate unassisted, and would be liable to burn out in holes, permitting an injurious excess of air to enter the furnace. This stoker burns only bituminous coal, and with a fair degree of smokelessness. It is not an automatic stoker, although considerably in advance of flat-grate hand firing.

Several patents have recently been taken out on modifications of existing British and American stokers, but they involve no new principles, and as far as is known to the writer none of them have yet been put on the market.

The Box mechanical stoker shown in Fig. 21 was patented by Alfred Box, of Philadelphia, Pa., in 1895. The grate bars are *U*-shaped in section, and have tuyere-shaped openings in the risers of the stepped fire surface, for the admission of air for combustion. The bars have a reciprocating motion for feeding the coal down the grate, which can be regulated as desired by an arrangement of pawls, ratchet-wheel and cam-tracks, which also control the corrugated feed roll in the hopper. This stoker is designed to burn small sized anthracite coal.

The Playford stoker, shown in Fig. 22, is substantially a copy of the chain-grate of the early Jukes stoker, combined with the removable frame of the Babcock & Wilcox stoker. Its construction exhibits no new features, the patents taken out in 1895 and 1896 being mainly for minor modifications of the grate and frame supporting it.

The American under-feed stoker was patented in 1896, by A. F. Brown, of

Dayton, Ohio, and D. F. Graham, of Springfield, Mass. Its construction will be easily understood from Figs. 23 and 24, showing the apparatus applied to a return tubular boiler. This device most closely resembles Holroyd Smith's stoker, shown in Fig. 11, the only material difference being the introduction of an air blast in the same manner as in the Jones under-feed stoker already described, and in the use of one tapering screw-conveyor instead of three, as in the Holroyd-Smith stoker. It consists of a hopper holding about 150 pounds of coal, to the bottom of which is connected a round cast iron tube, opening into a *V*-shaped trough, with a tapering screw-conveyor extending through them. On each side of the trough is placed an ordinary grate, filling the space between it and the side walls of the furnace. Along each side of the trough are placed "tuyere blocks," through which the air is forced at high pressure into the bed of coal as it is fed in by the screw-conveyor, as in the Schultz stoker, already described, which, by the way, was the first to use this method of feeding coal together with forced blast. By this combination a fairly smokeless combustion is obtained.

When the ash and cinder accumulate on the side grates, they are removed by hauling them out through doors on either side of the hopper, and quenching them with water, as in the ordinary hand-fired furnaces, and the bare grates covered by using a fire tool through the doors. This stoker burns bituminous coal only and has had the best success with low-grade fuel. A criticism has been made of stokers of this class,—that the method of introducing the blast concentrates the greatest heat in a narrow space immediately above the tuyeres, and is liable to cause strains in the boiler due to unequal expansion.

The Buckeye stoker is shown in Fig. 25, in a perspective view of the iron work, set up ready for brickwork. It was patented in 1896, by C. E. Greutner, of Salem, Ohio, and resembles in many points some of the stokers already described. The grate is composed of a short stationary section next to the

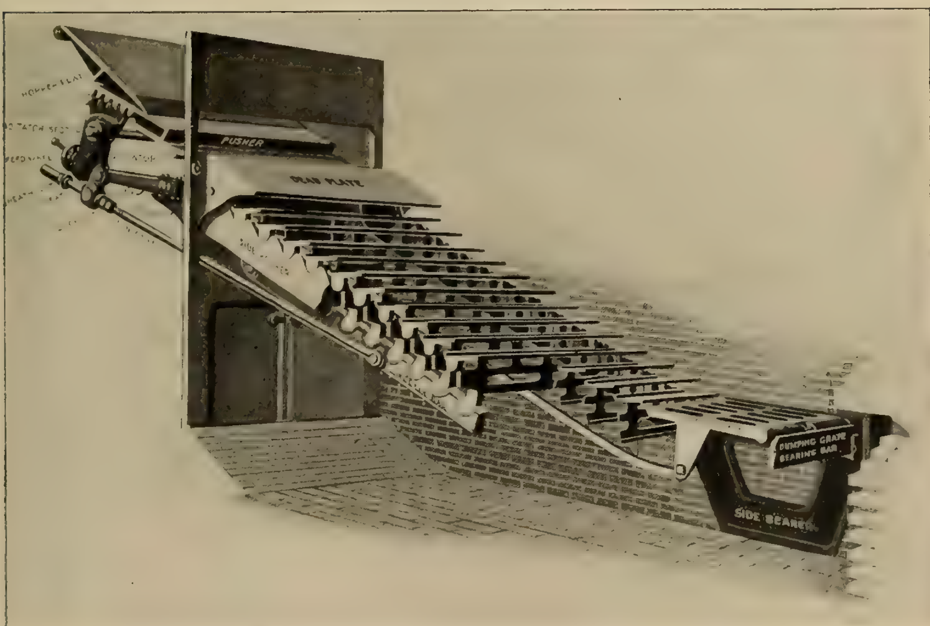


FIG. 27—A SECTIONAL PERSPECTIVE OF THE RONEY STOKER.

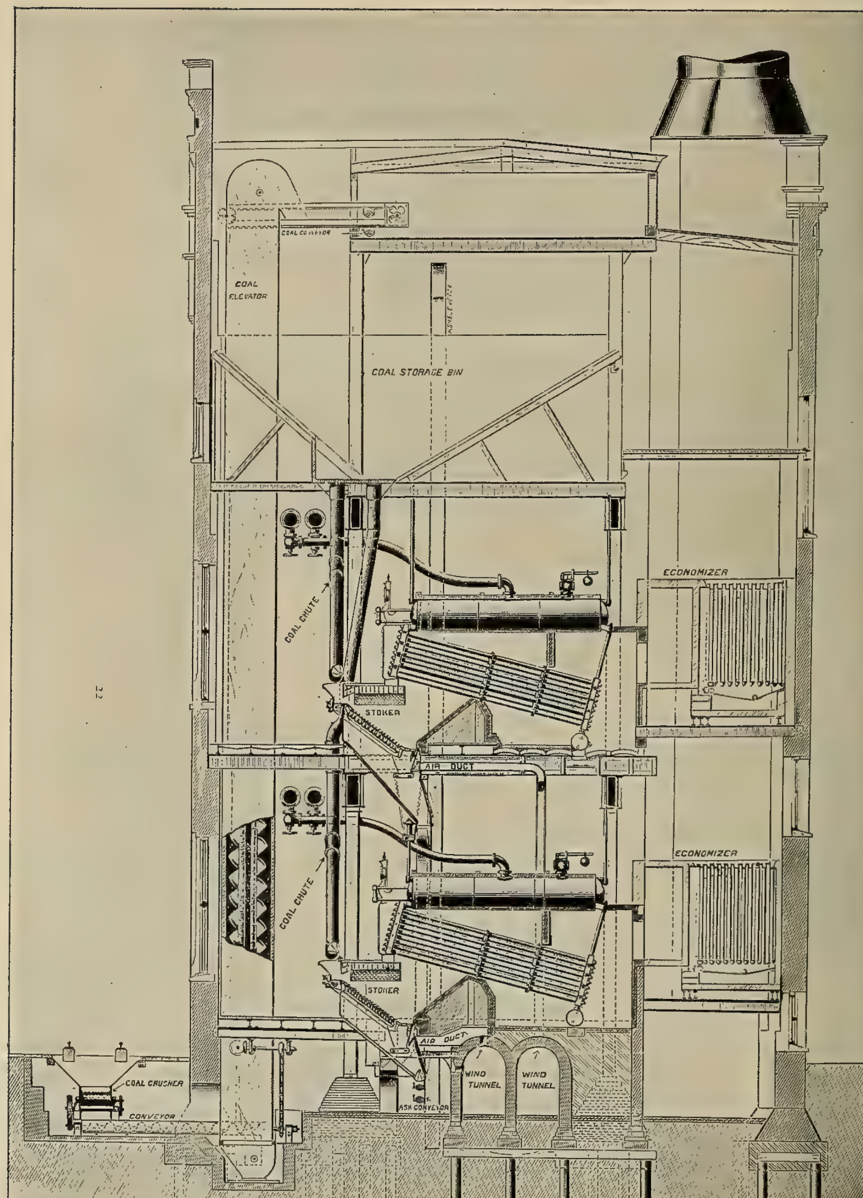


FIG. 28—SECTION OF BOILER HOUSE AT THE SPRECKELS SUGAR REFINERY, PHILADELPHIA, SHOWING RONEY MECHANICAL STOKERS IN OPERATION.

dead plate and a longer movable section, composed of parallel longitudinal bars, placed at an angle of about 30 degrees, with a dumping grate at the bottom. The movable grate is held in position by levers projecting through the front, on which are placed heavy counter-weights, so that, when desired, the upper ends of the bars can be lowered and the stoker fired by hand through doors in the front below the hopper. By means of lever connections the alternate grate bars can be raised and lowered two inches for the purpose of breaking up the bed of burning fuel. This stoker was designed to burn Western American bituminous slack coal.

The Roney stoker, already referred to, was brought out in 1885, after a series of experiments extending over about five years. Since that date it has been improved in various details of construction, and a number of additional patents have been taken out covering these improvements. Fig. 26 represents it applied to a return tubular boiler, and Figs. 27 and 29 show the details of the latest construction and the positions of the grate bars and feeding mechanism when in operation. It is a simple apparatus which receives the fuel in bulk, and, without further handling, feeds it continuously and at any desired rate to the furnace, burns the combustible portion and deposits the ash and cinder in the ash pit ready for removal.

In the bottom of the hopper is located a sliding pusher (see Figs. 27 and 29), actuated by a sector which engages a rack on the under side of the pusher, and by which it is given a reciprocating motion which gradually feeds the coal over the dead-plate and onto the grate. The latter consists of horizontal flat-surfaced overlapping bars extending from side to side of the furnace, carried on side-bearers extending from the throat of the hopper to the rear of the ash pit, and inclined at an angle of 37 degrees from the horizontal. In the wider furnaces two or more sets of grate-bars are placed side by side, provided with independent actuating connections. The bars in each set are coupled together by a rocker-bar, the notches of which engage with a lug on the lower rib of each grate-bar.

A variable reciprocating motion being given to the rocker-bar through a connecting rod, the grate-bars rock in unison, assuming alternately a stepped and an inclined position. (See Fig. 29.) The depending webs of the grate-

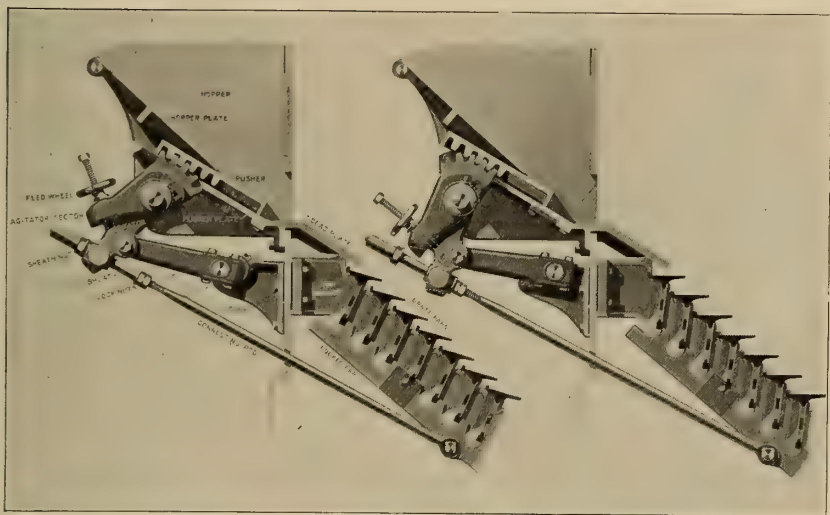


FIG. 29—RONEY STOKER DETAILS.

bars are perforated with longitudinal slots, so placed that the condition of the fire can be seen at all times and free access had to all parts of the grate without the opening of doors. These slots also serve an important purpose in furnishing an abundant supply of air for combustion. When the grate-bars rock forward into the inclined position the burning coal tends to work down in a body. But before it can move too far the bars rock back to the stepped position, checking the downward motion, breaking up the bed of fuel and admitting a free volume of air through the fire. This alternate starting and checking motion keeps the fire constantly stirred and opened up from underneath, and finally lands the cinder and ash on the dumping grate. From this it is discharged into the ash pit by releasing the dumping rod,—the work of but half a minute. All this is accomplished without opening the fire doors.

The actuating mechanism is simple, all motion being taken from one driving shaft extending across the boiler front and driven by a small engine. The power required has been found by test to be less than one-fifth H. P. for each 150 H. P. boiler. Motion is communicated by means of an eccentric or a crank and link to the "agitator," and thence to the "agitator-sector" and rack. Through the eye of the "agitator-sector" passes a stud screwed into the agitator, on which stud is a feed wheel by which the motion of the agitator-sector and pusher is regulated, the position of the feed-wheel on the stud determining the length of stroke of the pusher. The rock of the grate-bars is, in like manner, regulated by the position of the "sheath-nut" and "lock-nuts" on the connecting rod. By these two simple adjustments, within the comprehension of the ordinary fireman, the whole action of the stoker is controlled and the fires are forced, checked or banked at will.

A coking arch of fire brick is sprung across the furnace, covering the upper part of the grate and forming a gas producer whose action is to coke the fresh fuel and release its gases, which, mingling with heated air and steam, supplied in small streams through the perforated tile above the dead plate, is quickly burned in the large combustion chamber above the bed of incandescent coke on the lower part of the grate.

This stoker burns successfully and smokelessly all kinds of bituminous, semi-bituminous, lignite and anthracite coals. The complete regulation of the feed and grate motion, together with the method just described of supplying heated air and steam, adapt it to all the various coals used for steam-making. Waste products, such as tanbark, sawdust, cotton seed hulls and coke dust are frequently burned in this and other stokers.

From the foregoing it will be seen that most of the American stokers are of quite recent origin. In fact, less than ten years ago there were but three mechanical stokers made in the United States, viz., the Murphy, the Brightman and the Roney. The success attained by these three stokers has stimulated the inventive as well as the imitative genius of engineers and firemen, and mechanical stokers with varying degrees of merit and efficiency have sprung up on every hand. It is a curious fact, however, that almost without exception they are modifications of, or additions to, the features of stokers patented previous to 1886, either in the United States or in Europe.

The success attained by the different types of stokers has varied greatly, according to the conditions under which they are operated and the kind of coal burned, as well as the merits of the apparatus. Most of the stokers described were designed to burn bituminous coal, three being designed for anthracite alone, and only one handling bituminous, semi-bituminous, lignite and anthracite coals equally well.

The success of mechanical stoking is due to its recognised advantages over hand-firing, viz., economy in fuel, due to better combustion and the prevention of loss of heat caused by frequent opening of doors for firing and cleaning; saving in labour, where the plant is large enough to require more than one

man when fired by hand; steadiness of steam pressure, due to a uniformly high furnace temperature, and the ability to respond quickly to sudden demands for steam,—which naturally reduces the chances of explosions and lengthens the life of the boiler; and lastly, smokelessness or the ability to burn bituminous coal without smoke,—not consuming, but preventing it.

A properly designed stoker, properly handled, will effect a saving in fuel, over average hand-firing, of ten per cent. and upwards, according to the character of the hand-firing, which varies much more than stoker-firing. In addition to the saving in fuel, a properly constructed mechanical stoker reduces the number of firemen required, the amount of this reduction depending upon the number and arrangement of the boilers. Ordinarily, one man with the stoker will do the work of two or more, hand-firing. The greatest labour-saving, however, is gained when the boiler plant is large enough to warrant the use of coal and ash handling machinery in connection with mechanical stokers. With such an equipment it is possible to reduce the labour item to one-quarter of that of a hand-fired plant of similar size.

The developments of the last decade, in the economical burning of coal, makes it evident to the progressive engineer and manufacturer that the art of mechanical stoking is now so well advanced that it has become one of the most important departments of steam engineering. The best types of mechanical stokers have been on the market long enough to demonstrate their success, and to become standardised in the best types of new boiler plants; while the progress made on both sides of the Atlantic warrants the belief that in the near future mechanical stoking will become the standard method of boiler firing.

TECHNICAL EDUCATION IN GREAT BRITAIN AND FOREIGN COMPETITION.

By Sir William H. Bailey.

UNTIL recently, technical and higher commercial education has been much ignored in Great Britain. If, since the days of Elizabeth, half as much of the goodness and public piety and thought and work that have been given to the care of the poor and in the distribution of parish doles, had been devoted to the prevention of ignorance, those monuments to woe and past neglect, which are often the largest buildings in our towns,—the workhouses,—would long since have ceased to exist.

All are now agreed that education is a national concern. When Sidney Smith preached the funeral sermon of William the Fourth, he said:—" First and foremost, I think the new Queen should bend her mind to the serious consideration of educating her people." And a few years afterwards Lord Macaulay said: — " In this progressive country we neglect all that knowledge in which there is progress, to devote ourselves to those branches in which we are scarcely, if at all, superior to our ancestors. In this practical country knowledge of all that gives power over nature is left to be picked up by chance on a man's way through life."

Friends of education feel that now, amongst the great triumphs of the age of Victoria, we may count free libraries, board schools, and the technical colleges and institutions.

It is only reasonable to suppose that a student who knows all that has been written on any particular subject will be the most likely man to introduce and even invent improvements in that department. The study of the historical development of, say, the art of making bricks, should enable a man to make better and cheaper bricks than all his predecessors. Take the screw propeller, about which, even recently, some remarkable discoveries have been made in the direction of increased efficiency! This historical method should place any investigator in the front rank of possible discoverers.

History is truly the chief aid to the art of inventing, for it is the quickest and surest method of absorbing the wisdom of the past. The records of great inventors all inform us that this study enables a man to enrich and ennoble the future. History is a seed store, and happy is the man whose memory retains what he reads and who can utilise what he knows. Some years ago Dr. Gore wrote a book on the art of scientific discovery, and in his preface he pointed out that if scientific inventors were to publish their methods of work it would greatly assist scientific discovery.

The history of engineering tools and machinery is the story of civilisation. The two great ages of progress in Great Britain have been the reigns of the two great Queens, " the golden age " of Elizabeth and the " diamond age " of Victoria, and, by remarkable coincipences, both queens were heralded by the two greatest of all mechanical inventions.

Seventy-five years before Queen Elizabeth ascended the throne, Caxton had, in London, the first English printing press at work. He produced the " Ancient and Noble Histories of Prince

Arthur," "The Story of Troy," "The Golden Legend," "Reynard the Fox" and other works, and shortly after came from other presses the "Bible in the Vulgar Tongue." Then came Sir Thomas Moore's "Utopia," which loudly proclaimed that amongst all the Commonwealths of Great Britain that created by the smiths, carpenters and artisans was the chief one. It was the age of men of ideas, poets, discoverers, dreamers, and benefactors. The printing press increased each man's power among his fellows.

The heavens were opened, for men began to see with the new telescope, and, for the first time in the history of the world, human eyes saw the satellites of Jupiter. The barometer was invented and the atmosphere was weighed and the value of a vacuum and its laws were announced, and the new thermometer enabled men to measure heat and cold and use their forces, and to previse and predict, for knowledge of causes enables man to prophesy results.

The pendulum and the metronome were invented and music became scientific; the minute of time was divided into fractional seconds, and a new hand was given to clocks and watches. The infinitely little could be seen by the microscope, and Servetus and Harvey divided between them the honour of the discovery of the circulation of the blood. Continents and oceans, mountains and rivers were added to the maps, and new stars to the heavens.

The great herald of this illustrious age of Elizabeth was the printing press, and curiously coincident, also, about seventy-five years before Queen Victoria was crowned, James Watt, in Glasgow, was busy with his new steam engine, an invention second only in importance in its influence on the destinies and future of the human race to the printing press itself.

As I have just stated, the instruments invented in the age of Elizabeth have had a direct influence on the scientific inventions and discoveries beginning with the steam engine and electricity and ending with the marvellous discovery of Dr. Joule, of the mechanical equivalent of heat, which is the greatest discovery of the Victorian Era, for he gave to the world the rate of exchange between heat and work, the bank rate of fire and energy, and in all the class books of the schools of the world where engineering is taught the formula of this great Manchester discoverer is used.

His name will rank in history with that of Galileo, the inventor of the telescope and the pendulum; of Sir Isaac Newton, the discoverer of the laws of gravitation; of Dr. Priestley, the discoverer of oxygen; and other great discoverers of Nature's laws.

Technical education and foreign competition are receiving serious attention by all thoughtful men, and it may not be out of place to trace some of the causes which have helped to create the commercial supremacy of the great county of Lancashire. We owe all to the inventive skill and natural ability of the men within a few miles of this immediate district; John Kay, of Bury, invented the fly shuttle; Tom Hayes, of Leigh, invented the art of spinning by rollers; James Hargreaves, of Blackburn, invented the spinning jenny; Crompton, of Bolton, the mule; Radcliffe, of Stockport, improved the steam loom; and Richard Roberts, of Manchester, invented the self-acting mule.

Their improved methods of spinning and weaving increased the producing power of the works in Lancashire far more than fifty times, and it is useful for us to remember that before the year 1733, when Kay's invention was introduced, we were not superior to the natives of the Pacific Islands nor the pigmies of Central Africa in our methods of spinning and weaving. The robes of the Queen of Sheba, the vestments of the cavaliers, and, indeed, the garments of George the Second, were produced by methods of spinning and weaving as primitive and differing little from each other, and our great superiority commenced only when Kay introduced his fly shuttle, two pickers and a bit of string. I find that even up to 1803 we bought yarn from India, and it was only about seventy-five years before this that we began to cast our own iron hollow-

ware, most of it having come from Holland and Germany.

We imported Dutchmen at the beginning of the last century to teach us how to make pumps, and bleachers to show us how to bleach, and for a thousand years before the end of last century the cottonopolis of Europe was Barcelona, and if it had not been for our cheaper production, because of our mechanical inventions it might still be Cottonopolis.

I bought a note book the other day, published in 1676; it is the first cry for technical education in Great Britain. The title is "How to Outdo the Dutch Without Fighting," and it is written by Andrew Yarranton. The author says that "inasmuch as we cannot fight on the seas, as our boats are inferior to those of the Dutch, if we are to exist at all, we must sharpen the wits of our people," and he points out that mechanics' universities have existed for many years in Germany and Holland and that we should send there for teachers. He proceeds:—"Get a man from Freiburg to put us in the way of making tapes and to bring over two engines, one for narrow and one for broad tapes, with wheels to spin! Send for one man to Dort, in Holland, to put us into the way of treating the fine threads; for a spinning mistress from Germany to govern the little maids and instruct them in the art of spinning; and for a man from Haarlem, in Holland, to whiten your tapes and threads!"

I state these facts to show how comparatively recent has been British commercial success in manufacturing. Up to the beginning of last century nearly all the cast iron pans used in Great Britain came from Holland, but since then nearly all iron manufacture in Great Britain and the improvements generally up to a recent period have been British. We owe our great success chiefly to the singular natural ability of our inventors, most of whom had scanty education, but great imagination; but the inventors of the present day must be scholars and educated men. Sir Henry Bessemer is a scholar, Sir Lowthian Bell is a scholar, and the late Dr. Joule was a scholar and high-class mathematician. The trained scholars on the Continent who have the management of the iron and steel industries seriously affect the management of similar works in Great Britain, and unless we are more on the alert some of our industries will be annihilated.

The mechanical appliances and improved processes invented by Englishmen in the middle of the last century caused us to be superior to our trade rivals abroad, and we must not be astonished when we are told, what I know to be true, that in America and in Germany and in France many improved methods are being discovered which, in some cases, are very much superior to ours.

The factory system that has been so successful in textile manufactures is being introduced into the production of machinery, and the hand lathe and the common drilling machine will shortly be ancient tools, fit only for the jobbing smith. It is for our manufacturers and captains of industry to study carefully the new movement, in order that we may retain and strengthen those manufactures which are being assailed.

There are dark clouds in the commercial sky; but they will roll away, for the pluck, patience and enterprise which have taken our ships to every sea and made our steam whistles sound in every port and harbour of the world, and the paddle wheels of British boats pulsate beyond the tortuous cataracts of the ancient Nile, and British axes ring in the backwoods of Canada, still exist in the men of our race and blood.

FLOATING DOCKS.

By Sydney F. Staples, A. M. Inst. C. E.

IN writing an article upon the subject of floating docks the most logical way to commence seems to be to inquire why such docks came to be invented and used, and to arrive at a satisfactory solution to this question one must look to the natural conditions which existed at the places where such docks were brought into existence.

In very early days ships of any size were docked by grounding them at high water and then waiting for the tide to recede, work being proceeded with until the tide again rose. This method was improved upon by hollowing out a berth or small basin, and then, when the water was down, a temporary dam would be made across the entrance to the basin where the ship lay, so that work could go on uninterrupted by the rising tide. Here, then, we find the germ of the idea of a graving dock, the essential factor of which was the existence of the rise and fall of the tide, and it was due to the absence of tide that we owe the original floating dock.

In the time of Peter the Great, the captain of a British ship, finding that his vessel, in Cronstadt Harbour, was in want of docking, and that, owing to the absence of tide in the Baltic Sea the then orthodox method was impracticable, obtained a hulk named the *Camel* and completely removed the whole of her decks and internal work, cut off one end and fitted it with a gate. He then berthed his ship inside the hollow hull of the *Camel*, closed the gate, and pumped the water from its interior.

This is the very first instance on record of the use of a floating dock, and it was directly brought about by the absence of the hitherto essential tide. The almost tideless shores of the United States may be termed the nursery of the floating dock, and even to this day we find that there are twenty-three floating docks in the Port of New York, and only five graving docks. Another natural feature favouring the growth of these docks in America is the extreme difficulty experienced in many ports in obtaining a good foundation for a graving dock ; floating docks are quite independent of such considerations.

A true floating dock may be described as a structure which utilises its displacement for lifting a ship so much above its normal draught line as to bring the keel above the level of the water's surface. In the case of a graving dock the water is taken away from the ship, and in the case of a floating dock the ship is taken away from the water.

The principle upon which a floating dock works depends upon the fact that if any given quantity of water be removed from the interior of a hollow submerged vessel of any form, the upward pressure exerted by the surrounding water is exactly equal to the weight of the water that has been removed, and herein lies one of the great advantages which a floating dock possesses over a graving dock, inasmuch as the energy to be expended in lifting a ship is exactly proportional to the work to be done, plus a small constant.

Thus, for a small ship a small amount of water has to be pumped out of the dock to lift her, whereas in a graving dock, the smaller the ship, the greater

MESSRS. CLARK & STANDFIELD'S FLOATING GRAVING DOCK.

is the space in the dock unoccupied by her, and consequently the more water has to be pumped out, and it is only in the case of the largest ships that the dock can contain that the two systems approach one another in economy of working.

The first floating dock in Great Britain was built in 1776 by a shipwright of the name of Aldersly, and a few years later another was built on the Thames by Watson. These were similar in idea to the original *Camel* dock. Docks of the same type were also constructed for other ports, but their action must have been somewhat unsatisfactory, owing to the absence of means of regulating their descent, or of ensuring their stability during lifting or lowering. In later instances of this type, we find that they were kept steady by being worked between parallel rows of piling. When it came to be proposed to construct these docks of iron instead of timber, some means of regulating their descent became necessary to prevent them from going right to the bottom, and so it came about that the platform and side walls were made hollow, and means were provided for pumping the water from their interior, so as to utilise their displacement, and as early as 1809 we find that a large dock with hollow pontoon and sides was designed; but this was never built.

In America floating docks were greatly improved by Captain John Thomas, and in 1834 a patent was taken out by him for a sectional dock. Docks of this type are at work in America to this day with various modifications, notable among them the Philadel-

phia dock, built by the United States Government in 1847. This was the first of its kind. As shown in the illustration on page 341, it was part of a scheme for storing men-of-war under cover.

A sectional dock, as its name implies, is composed of short lengths or sections, joined together so as to make up any desired length. In this case there were six lengths of 32 feet, and three of 30 feet. Any required number of these were joined together, according to the length of the ship to be lifted. They were all 105 feet wide, and carried at each end a hollow frame-work of such a height that the house on top of it was above the water when the dock was lowered to receive a ship.

Each frame-work acted as guide to a float, in the form of a rectangular tank, ated by the engine, the shaft on each section being coupled by a universal joint to that on the next. The dock was built of timber, and it was caused to sink by admitting water into the pontoon and by raising up the floats so that their weight depressed the dock to the required depth. The ship was next hauled into the dock and the floats were lowered into the water. This caused the dock to come up against the ship which was then berthed and shored. Upon the water being pumped from the pontoon, the ship was gradually lifted clear above the surface. The dock with the ship on it was then towed into a shallow basin and lowered until it rested on the bottom, but still with the deck of the pontoon above the water. The ship was then blocked up on a sliding cradle and by means of hydraulic machinery

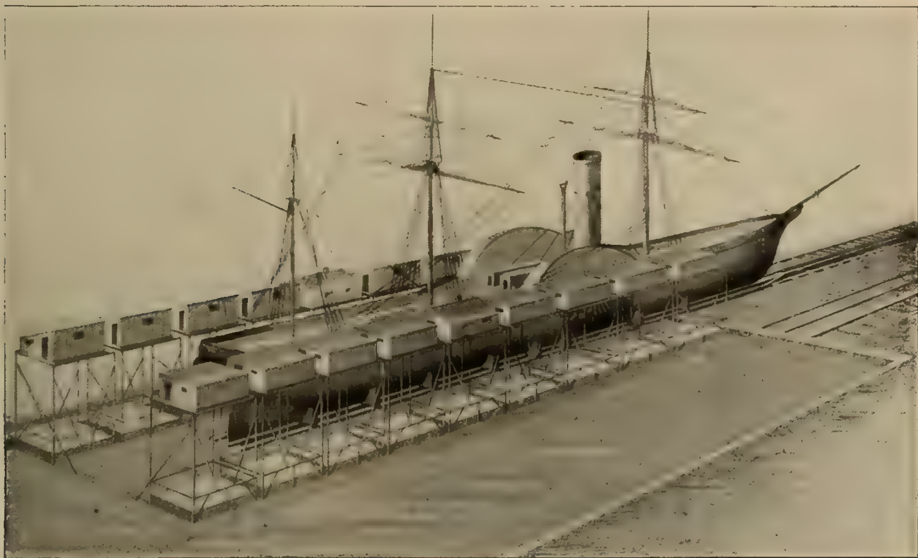
THE "CAMEL" TYPE OF DOCK, STILL IN USE AT WYVENHOE.

which could be made to work up and down by a rack and worm wheel. In the large house on each side of the centre section of the dock was placed the engine for working the pumps. Each section had three plunger pumps on each side, worked by shafting actu- was hauled ashore. This dock was the first that possessed the most important feature of being able to dock itself without extraneous aid, as one section at a time could be lifted on two other sections and its under water portions could be got at for the purposes of repair.

THE ST. THOMAS, WEST INDIES, DOCK, BUILT IN 1867.

An important modification of this type of dock is the one designed by Mr. (now Sir Frederick) Bramwell in the year 1867 for St. Thomas, in the West Indies. The pontoons in this case were separate, for the purpose of self-docking, but the sides of the dock consisted of continuous lattice girders instead of being each a separate section, the same as the pontoons. This was done so as to obviate the weak point of the sectional dock, namely, its almost complete want of longitudinal strength. This dock has been a great success and is at work earning dividends to the present day.

Another early type of floating dock, still largely used in America, is the balance dock. This was invented by John S. Gilbert, and the first one was constructed in Portsmouth in 1848 for the American Government. It is built all in one piece and it differs from the sectional dock, or the St. Thomas, in that the side walls are closed in similarly to the pontoons. The dock, being of wood, will not sink sufficiently of its own accord even when water is allowed to run in and fill the sides and pontoon, and a water-tight deck is, therefore, fitted near the top of the walls into which water can be pumped, its weight causing the dock to sink as low as is desired. These upper chambers are called the balance chambers from the fact that the admission and emission of water from them were the means by which the dock was always kept on an even keel. The weak point of this dock lies in the inability of getting at its under-water portions for the purpose of repairs. This dock was also fitted with end gates, so that in the event of a heavy ship being lifted, they could be placed in position, and when pumping the water from the interior of the dock was not sufficient to bring the keel above the surface the gates would enable the whole ship to be got at, as they allowed the water from the pound, formed by them and the sides and bottom of the dock, to be pumped out.



REPRODUCED FROM "STUART'S NAVAL DRY DOCKS OF THE UNITED STATES."

THE PHILADELPHIA SECTIONAL DOCK, BUILT IN 1847.

The Bermuda dock is perhaps the most widely known floating dock that has ever been constructed. It was designed by Rennie, and was towed out to its destination by two ironclads in the year 1869. It was constructed on the

AN EARLY DEPOSITING DOCK. DESIGNED BY JOHN STANDFIELD.

principle of the balance dock, but instead of being rectangular in section, it was U-shaped, and in addition to numerous longitudinal and transverse watertight bulkheads it had several watertight decks. The object of the particular shape of this dock was to enable it to be careened by pumping water into the upper compartments of one side, the rest being quite empty, so that the bottom of the dock could be got at.

This careening to such a large angle as would be necessary for the purpose was found to be a difficult and dangerous operation, and although it was successfully carried out in Portsmouth Harbour, it was never attempted subsequently. It was fitted with end gates, and with these in place, it was capable of lifting the heaviest ironclads of the day. After some years the iron forming the hull of the dock began to deteriorate considerably owing to the impossibility of getting at its underwater parts to paint them. The pontoon and part of the walls, therefore, were filled up with concrete and it is now used as an ordinary graving dock.

As showing the immense improvements that have been made in the design and construction of these docks, it is interesting to note that whereas in the Bermuda dock no less than 8600 tons of material were used, only 4537 tons, or a little more than half, were required for the floating graving dock lately sent out to Havana. Yet both docks were capable of lifting the same weight, viz., 10,000 tons.

A notable advance on the design of floating docks was made by the late John Standfield by doing away with one of the two sides or walls, which up to that time had been considered essential. His original idea was a dock whose pontoon or platform consisted of hollow iron cylinders, with spaces between them, upon which the vessel rested and which gave the required buoyancy. This platform was held between two walls, composed of large cylinders on end, connected together at top and bottom, one of which could be detached from the rest of the structure. When this was done, the ship was left supported on a dock, of which the end view was like the letter *L*. To give the loose wall the requisite stability when separated from

DEPOSITING DOCK AT BARROW-IN-FURNESS, ENGLAND.

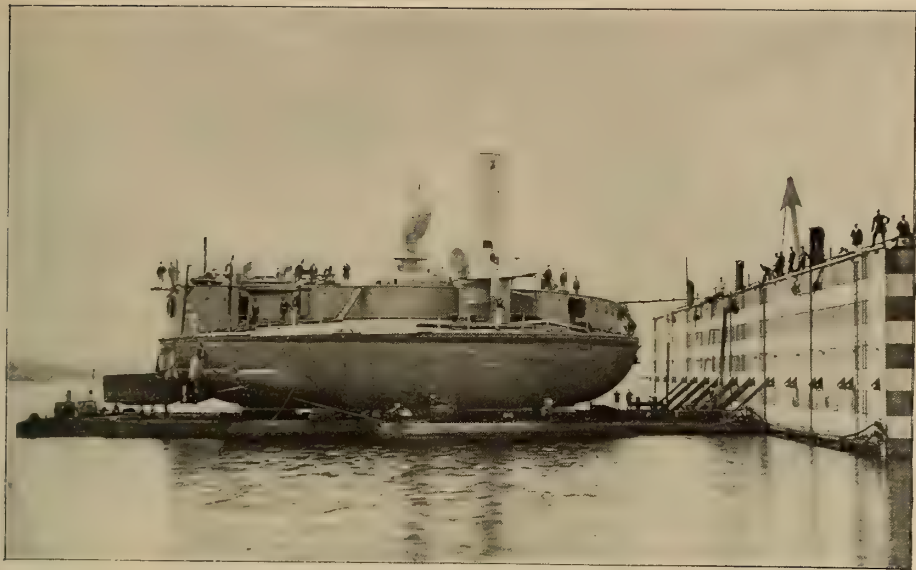
the rest of the dock, it was attached to a floating outrigger by means of two sets of parallel booms working on pins. The next step in the evolution of the single-sided dock was to do away with the removable wall altogether and to attach the outrigger to the back of the wall that was left.

The object of making the platform in sections or fingers, the ends of which were not connected, was to allow of the dock on it being warped broadside to a grid, the separate fingers of which passed between the tubes forming the pontoon of the dock. It is obvious that, when in this position, if water be admitted into the dock, it would sink and leave the ship deposited on the grid or staging, while the dock could be towed away and be ready to lift another ship and similarly deposit it, and so on according to the extent of the staging. It was but a short step, but an economically important one, to alter the tubular fingers of the platform to a rectangular section and to make the wall continuous, and this is the form in which depositing docks are built to the present day.

The first of the depositing docks was built in 1876 for the Russian Navy in order to dock the circular ironclads which were, at that time, being constructed. Owing to their immense beam (120 feet in some cases) there was no dock in the world that could accommodate them. An ordinary double-sided floating dock possesses the power of taking ships considerably longer than itself, but if the dock has only one wall, it is obvious that the ship may not only possess greater length than the dock, but greater beam as well. The first of these docks was installed at Nicolaieff, on the Black Sea, but was subsequently towed to Sebastopol where it is still in service.

This incidentally draws attention to one of the features of floating docks which is of great importance, viz., the ease with which they can be towed from one port to another should circum-

THE ST. JOHNS, NEWFOUNDLAND, SECTIONAL BALANCE DOCK.



THE DEPOSITING DOCK AT NICOLAIEFF, RUSSIA, LIFTING A CIRCULAR IRONCLAD.

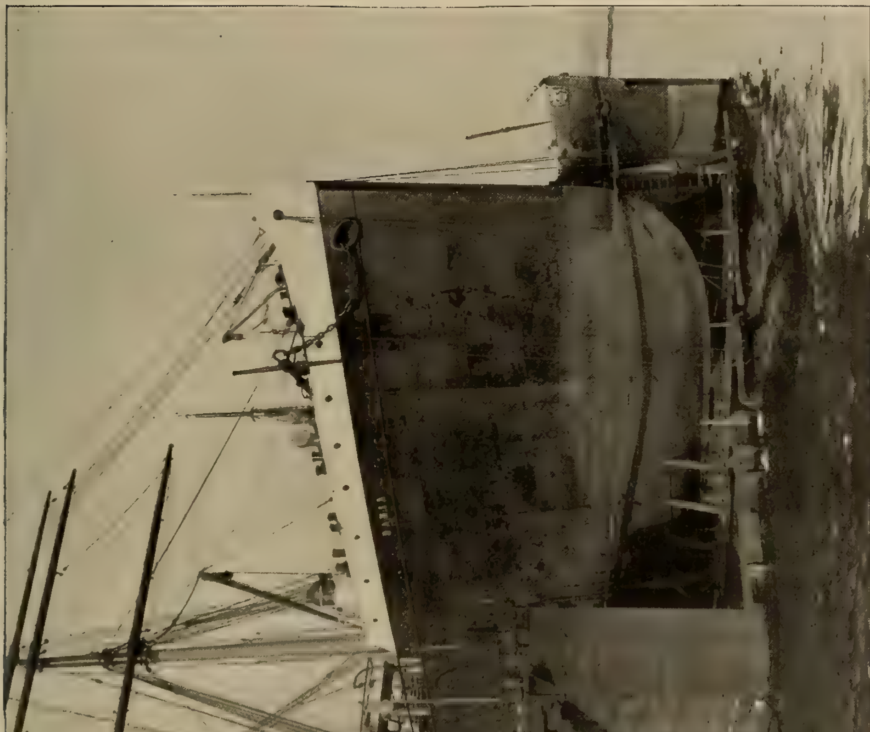
stances require it. It will be seen from the illustration of the Barrow dock on page 346, that if a one-sided dock be made in two lengths, which, in the ordinary way, are bolted together, but which can be taken apart upon occasion it possesses a very simple and efficient means of docking itself. It is obviously more essential that an iron or steel structure, like a floating dock, which is always in the water should possess the power of enabling all its underwater portions to be easily got at. Without this power the life of such a structure is short, but if as is the case with Clark & Standfield's docks, it possesses that power, its life is practically unlimited.

The off-shore dock is another form of single-sided dock and one which has met with very great success. In this case the floating outrigger is dispensed with, and upright columns, strongly braced, are substituted. These columns, which are firmly fixed on piles or cylinders, take the booms and give stability to the dock during the operations of raising or lowering. It is obvious that by this means very much greater stability can be given to the dock than would be possible with an outrigger of any practicable size, but at the same time it is equally obvious that should the dock, from any cause, tend to get out of level, some means of indicating this tendency and of partly or entirely taking it up must be devised, for if the booms were merely hinged on to the upright columns there might be a very great and unknown strain put upon them, owing to the impossibility of pumping exactly evenly, and the first indication of this would be the failure of some part of the structure which might mean disaster.

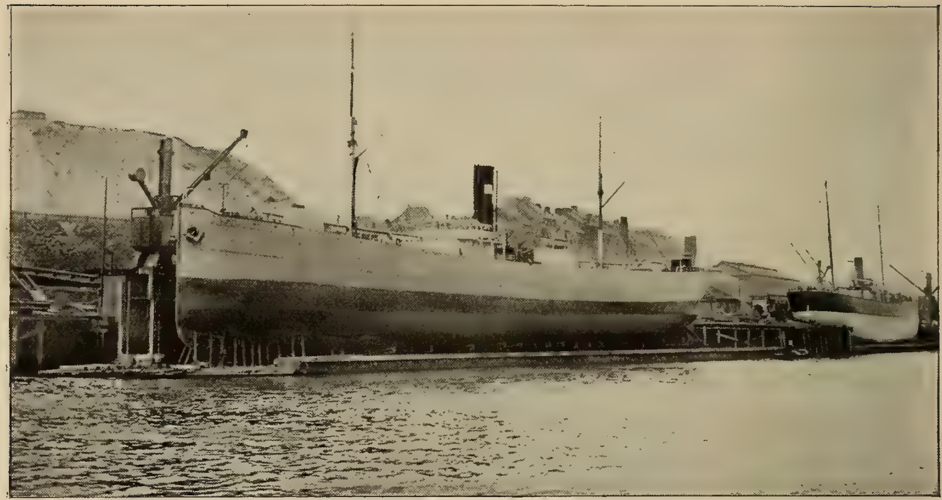
The upper boom, instead of being pivotted directly on to the shore column, is hung on to a plate which is suspended a few inches higher up by a pin on the column. If a pull or push be transmitted down this boom, it is clear that the tendency will be to make this plate to stand out at right angles to the column. This is opposed by heavy weights hung to the bottom of the plate, which by this means steadies the dock and at the same time acts as an indicator showing which way it is trying to tip.

As an off-shore dock is permanently attached to the shore, it is unnecessary to make the platform in the shape of separate caissons, so the fingers of the

THE BARROW DEPOSITING DOCK, LIFTING PART OF ITSELF FOR PAINTING.



THE HAMBURG OFF-SHORE DOCK.



SMITH'S OFF-SHORE DOCK AT NORTH SHIELDS-ON-THE-TYNE, ENGLAND, SHOWING SHIPS LIFTED WHICH HAVE BEEN SHEERED ON SIDEWAYS.

depositing dock are plated in, thereby adding to the lifting power of the dock at a very slight expenditure of material. This type of dock is undoubtedly the most economical form of ship-lifting apparatus in existence for any but the very smallest size of vessels.

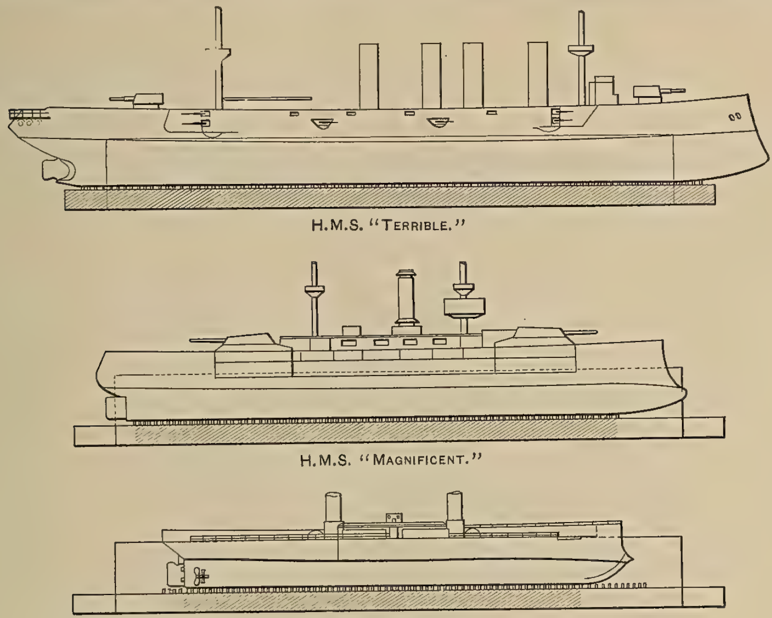
In many places where ship-repairing is carried on, the line of quays is on the side of a river or estuary, and it is in such positions that the great advantage of a one-sided dock, fixed alongside a quay, is apparent, as a ship cannot only enter the dock at either end, but, by attaching a hawser to a buoy or dolphin up-stream, she can be warped on sideways. A graving dock in a similar situation would almost necessarily be

LAUNCHING THE HAVANA FLOATING DOCK.

placed at right angles to the stream, and consequently, owing to the risk of the current forcing her against the entrance of the dock, a vessel could enter or leave only at slack water, thus incurring a loss of time, which might be, and very often is, of the very greatest importance.

A short time ago Messrs. Clark & Standfield, of London, were called upon to design a dock for a port with a very flat fore-shore, with no deep water within 300 feet of the land, and at the same time it was desirable to save the large waste of time caused by ferrying all materials and tools to and from the ships on the dock. In this case a combination was adopted of the two types of single sided docks above referred to, by taking the dock portion of the off-shore and attaching its booms to upright columns on a floating outrigger, as if it had been a depositor. The outrigger in this case serves as a floating workshop, and the boilers for driving the dock engines, electric light plant and other machinery are situated on it. For a sheltered position this makes an exceedingly good combination where a depositing dock is not required and where an off-shore dock, owing to the nature of the site, is impracticable.

At the end of the year 1896 the Spanish Government called for designs and tenders for a floating dock to conform to conditions which were particularly onerous. It had to be of sufficient lifting power to take a battleship of 10,000 tons, which is a heavy, but comparatively short, vessel; it had also to be capable of lifting any cruiser up to a length of 500 feet and it had to work in a minimum depth of water. The dock had also to be delivered complete in the harbour of Havana within eleven months from the date of the contract being signed in Madrid.



H.M.S. "Terrible."

H.M.S. "Magnificent."

H.M.S. "Inflexible."

THE SHADED PORTIONS REPRESENT THE BEARING LENGTH OF THE SHIP.

COMPARISON OF LENGTH OF KEEL, BEARING ON BLOCKS, OF DIFFERENT TYPES OF WAR VESSELS.

One of the chief difficulties to be got over in the case of lifting a short, heavy vessel, like a first-class ironclad, upon a dock long enough to take a cruiser, lies in the fact that the bearing surface of the keel is so very short that the dock must necessarily be longer than

THE HAVANA FLOATING GRAVING DOCK, STARTING FROM ENGLAND TO CROSS THE ATLANTIC.

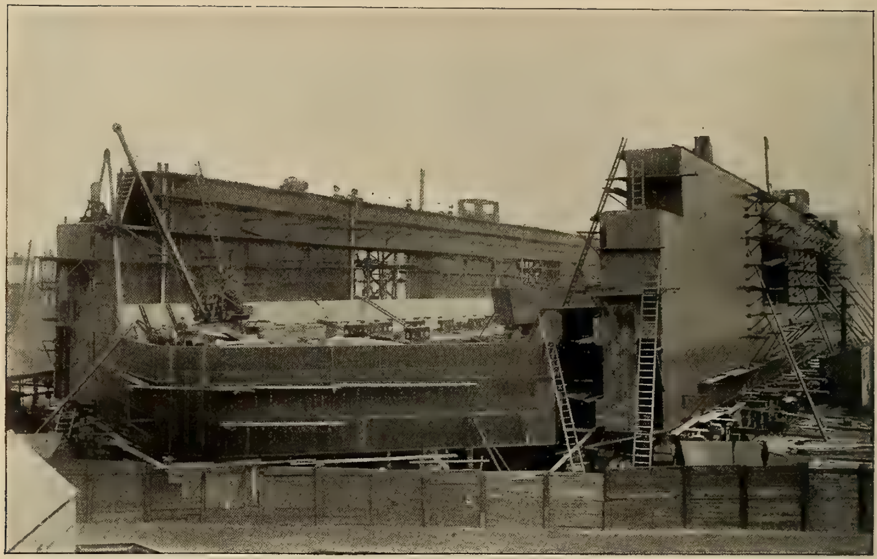
this. If the dock, as practically is the case, is longer than the bearing length of the vessel, it follows that when the water is pumped from the ends of the pontoon, as well as from those portions on which the ship rests, these ends tend to curl slightly upwards owing to the pressure of the water below not being balanced by any weight above. This, of course, means that the fore-and-aft ends of the keel of the ship have a very much greater strain to bear than the rest, and, to take an extreme case, it might be conceived that the ship would be bearing entirely on two or three blocks at each end. Such a proceeding would strain any ship and also the walls of the dock, and no government would care to risk a first-class line of battleship upon such a structure.

This difficulty is entirely avoided in Clark & Standfield's floating graving dock, the invention of Mr. Lyonel Clark, a member of the firm. As its name implies, this is practically a combination of a graving and a floating dock. It consists essentially of a double-sided floating dock with the pontoon in three or more separate sections whose walls are a little longer than the length of the largest battleship the dock has to take, and a pontoon of sufficient length for the largest cruiser. At each end of the walls there are slots which can take light caissons, to be utilised as described later.

As this may be taken as the highest development of floating docks at the present time it may be of interest to describe one of them in somewhat closer detail than has been done in the case of the docks previously mentioned. The Havana dock may be taken as a type. The total length of platform on which the ship rests is in this case 450 feet, consisting of three central pontoons, each 75 feet long, and two pointed end pontoons 108 feet, 4 inches long, the balance of length being made up by the spaces between them.

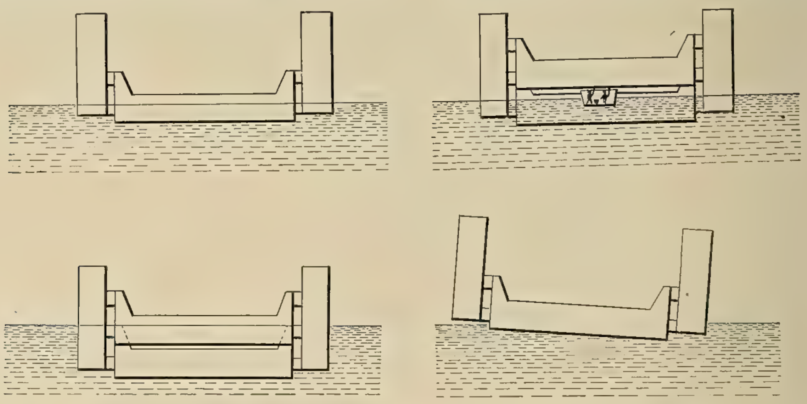
VIEW OF THE HAVANA DOCK IN AN EARLY STAGE OF CONSTRUCTION.

The object of making the pontoon in five separate parts is to enable the under-water portions of the dock to be got at without having recourse to extraneous appliances. When the bottom of a pontoon has to be examined, the



ANOTHER CONSTRUCTION VIEW OF THE HAVANA DOCK.

dock is pumped out, and by knocking out a few large pins on either side the pontoon is detached from the rest of the dock which is then sunk. When it has been lowered to such a level that the loose pontoon is floating opposite to attachments which are placed near the top



SELF-DOCKING ARRANGEMENTS OF A FLOATING GRAVING DOCK.

of the walls for the purpose, it is bolted on to the main body of the dock once more. If now the water is pumped out of the dock, it is obvious that the pontoon will be lifted in the air above the surface of the water, and its under side will be accessible for the purposes of cleaning or repairs. The side walls of the dock are cleaned under their water line by merely careening the dock. As they do not extend quite to the bottom of the pontoon, the angle through which they have to be tilted is very small.

This dock is divided into thirty watertight compartments, each of which has its own pipe and valve, so as to have the dock completely under control. At the centre of each wall there is a valve house where all the valve rods are collected, and thus the whole direction of the dock is placed in the hands of two

men, one on each side. The pumps are worked electrically, each one having its own motor, driven from the central engine in the wall, and in the valve house are the starting and stopping switches. The great feature aimed at in the controlling of the dock is to bring everything to one point in order that the man in charge may not have to leave his post to attend to anything, but can do all that is required within the four walls of the valve house.

When an ironclad has to be lifted, the end compartments of the pontoon will not be worked at all, as the dock has sufficient displacement without them to lift the vessel until it draws only eight feet or less; then the end caissons come into play. These caissons, having to work only against such a very small head of water, are very light affairs. When they are placed in position, the water is pumped out from the deck of the pontoon and the ironclad is left completely dry, without any chance of either straining itself or the dock. The total time required for the docking of a 10,000-ton battleship is about two and one-half hours.

Large openings are left in the walls which allow a free play of light and air to the ship on the dock, and as the gates are only about eight feet high they offer no obstruction to a free current of air. The ship is thus placed in the best possible condition for being worked upon and for the paint on her outside to dry, under very different conditions to being placed at the bottom of a graving dock, where there is comparatively little light and no circulation of air.

The dock was towed 6500 miles across the Atlantic from the yard of Messrs. Swan & Hunter, of Wallsend-on-Tyne, to Havana in 58 days, which may be considered very good progress.

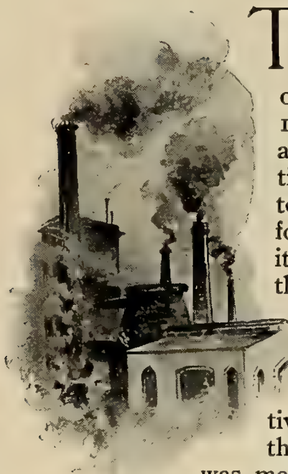
There is one more point to which the writer would draw attention in connection with these floating graving docks, and it has been intentionally left to the last in order to draw special attention to it on account of its extreme importance. In war time nothing is more likely than that battleships will come into port leaking, down by the head, with decks perhaps nearly awash or with a bad list, and there is hardly a graving dock in the world that is capable of receiving a ship in this condition. The largest British stone docks are described as having about 33 feet of water over the sill at the extreme top of ordinary spring tides. This means that a ship of the type of H. M. S. *Revenge*, having her draught increased by as little as 6 feet, could not get into dock even when on an even keel, and if she were listed as little as 5 degrees, an increase of draught of only 3 feet 6 inches would block her, and if her angle of heel were increased to the quite possible amount of 10 degrees, a mere increase of 18 inches in her draught would make her bilge keels foul the entrance of even the newest and largest British docks, and that at high-water spring tides. By lowering the keel blocks and by allowing somewhat less freeboard than usual to the dock when it is lowered to receive the ship, an extra draught of 3 or 4 feet can always be obtained in a floating dock, and, should the vessel have a list, nothing is easier than to give the dock a similar list. Then, when the dock is pumped up on an even keel, the ship will be in the same condition.

There can be no doubt that the floating graving dock is the most efficient form of dock in existence. The first cost is, on an average, only about one-third of the cost of a stone dock to take the same size of vessels; owing to the facilities with which the dock's under-water portions can be got at, its life is practically unlimited; it can be constructed in a comparatively short time (a dock of this type to lift 11,000 tons is now being constructed and has to be delivered ready for work within nine months from the date of the order being given); it can easily and safely be towed to any part of the world; and last, but not least, a ship on such a dock is placed in a very favourable position for repairs or painting. It is therefore hardly to be wondered at that docks of this type are now being installed in many parts of the world, both as adjuncts to ship-yards as well as dividend-earning concerns on their own account.

RECOVERING TAR AND AMMONIA FROM BLAST FURNACE GASES.

By Andrew Gillespie.

A Paper Originally Presented to the Institute of Engineers and Shipbuilders of Scotland and Revised Especially for Publication in this Magazine.



THOUGH coal tar as a distillate from coal was known for over a century before 1798, having made its appearance in connection with various attempts to make coke for smelting purposes, it was not till about that time, when William Murdoch made his discovery of illuminating gas from the destructive distillation of coal, that tar as a product was made in such quantities as to demand separate attention. At first, it was got rid of as a "nuisance," and ultimately it was found to have such distinct values of its own as to remove the reproach of by-product, and bring it into line with original processes.

As to the "nuisance," it may be said that within living memory it seemed practically impossible to get rid of the tar, and as to value, coal tar now counts over fifty constituents of separate commercial importance.

As this fact came to be realised, together with the growing necessity for economising fuel, attention was directed to the waste of coal gases seen burning at the top of blast furnaces. Until comparatively recent years it was considered that the coal put into a blast furnace had done its whole work when the ore was smelted and run into pigs, the air of the hot blast being heated by additional coal in a separate stove. The first step in the utilisation of the waste gases was in closing the furnace tops, and passing the gases, so confined, by a system of piping to the boilers for raising steam for the blowing engines, and to the air stoves for heating the blast. This was a clear saving of all the coal used outside the furnaces, and the next step was taken when it became evident that the tar which revealed itself in the green gas coming from the closed furnace top, causing trouble and discomfort in the combustion of the gases, might not only be removed, but turned to advantage, as had been done in the production of illuminating gas.

The initial difficulty in the treatment of such gases lies in their enormous volume. The quantity of gas obtained from a ton of coal, distilled in ordinary retorts for illuminating purposes, is about 10,000 cubic feet, while from the presence of the air blast, mixing with the coal gas distilled in the process of smelting, the volume is increased to about 130,000 cubic feet, or thirteen times the quantity of illuminating gas. The valuable by-products which come from the coal alone are thus diffused through the entire volume, and to recover them it is necessary to deal with the whole. To give some concrete comparison of such a large volume, it may be stated that the largest output of gas from the whole of the Corporation Works in the Glasgow district is under 30 million cubic feet per 24 hours, while the volume coming from four blast furnaces is over 40 millions, requiring a collecting main of 8 feet diameter.

The next difficulty lies in the high heat of the gases, which pass by the collecting main to the recovery plant at a temperature of about 300 degrees F.,

and this must be reduced to under 70 degrees before ammonia can be properly recovered, the tar being meantime obtained in the process between these limits of temperature.

It thus becomes apparent that the apparatus must be on a very large scale, while the difficulty and expense is increased by the fact that the combined gases form an approximately explosive mixture, rendering it necessary to make provision against possible danger.

The first attempt to recover the tar and ammonia from blast furnace gases was carried out about 16 years by Messrs. M'Cosh and Alexander, of the Gartsherrie Iron Works, and known as the Gartsherrie process. Other methods followed, all more or less based on the ordinary process of removing the tar and ammonia from illuminating gas, differing chiefly in dimensions, till now nearly all the active blast furnaces in Scotland have been furnished with a recovery plant of one form or another.

As yet scarcely any of the furnaces in England are so equipped, the smelting in them being effected chiefly by coke instead of raw coal. In a few cases the products have been extracted from the ovens in preparation of the coke, but, as a rule, the product-bearing gases are neglected.

It might be supposed that while the recovery of the ammonia from the blast furnace gas does not reduce the calorific value, the extraction of the tar compounds would have such a result; but, practically, this has not been found to be the case, for the clean gas, after the recovery process, is in better condition for burning under the steam boilers and in the hot air stoves than when it was laden with tar and dust, and it is clearly proved that from the same coal put into the furnace, or, more accurately, from the surplus gases generated from the coal in combustion, is derived the heat energy sufficient to drive the blowing engines and heat the air of the blast to 1700 degrees F., plus the oil, pitch, and sulphate of ammonia obtained in the recovery plant.

To put this again into concrete form, it may be stated that the results obtained from a plant, recently erected in connection with four furnaces, show that, in addition to the usual output of pig iron, the clean gas raises steam in 17 large high-pressure boilers, heats the air in 3 regenerative stoves, distils the tar into oil and pitch, and evaporates the waste liquor, while the recovered tar yields 7 gallons of oil and 86 pounds of pitch, and the ammonia liquor, 25½ pounds sulphate of ammonia per ton of coal put into the furnaces. The total recovery for 1895 from 92,940 tons of coal, carbonised in the four furnaces, amounted to 677,000 gallons of oil, 3550 tons of pitch, and 1057 tons of sulphate of ammonia.

As we are not concerned with the gases in combustion in the boshes or hottest part of the blast furnace, where the ore is being reduced, but with those that form between the burden of raw coal and iron ore and the closed top, and which we may term the surplus or green gases, these, prevented from access to the air and consequent ignition, pass by the open valve of the downcomer tube from each furnace to the collecting main. The green gas is drawn through the main by exhausters placed further on in the plant, and the high temperature is preserved as far as possible by a firebrick lining inside the main. The gas then enters the first vessel in the process, the "tar washer," which is a large oblong-shaped tank having the bottom ridged and sloping to each end. Internally there are two compartments, formed by longitudinal partitions, to give a double wash; the partitions are fitted with serpentine diaphragms having serrated edges. When in operation, the compartments are charged with tar till it rises above or seals the edges of diaphragms, rendering it impossible for the gas to pass, except by washing through the tar; the gas is drawn through the seal by the power of the vacuum formed by the exhausters, and the entire area is continuously agitated, with the double result—first, that the hot gases partially distil the water out of the tar, and,

second, the contact with the tar in the washer entangles the tar particles in the gas and precipitates them on the sloping bottom, whence the heavier tars are run off at intervals to the stock tank. Along with the heavier tars, the gas has lost in this washer about 130 degrees of its heat, and is ready for the final cooling in the "condenser."

The condenser is divided into eight sections, each having a separate chest fitted with 18 pairs of 20-inch diameter pipes, 54 feet high; an arrangement is made in the chest, so that the gas passes up one pair and down the next continuously, till, by the time it reaches the final pair, the exposure to the atmosphere has reduced the temperature to 70 degrees and under. In warm weather it is necessary to supplement this cooling by a spray of water on the top of each pipe which runs down the outer surface, both reducing and equalising the temperature. The lighter tars and weak ammonia liquor, separated from the gas in condensing, are collected from each section, and pass into a "separator," where, by the difference in their specific gravities, the tar and liquor are automatically separated.

The gas now passes by double branches into the first "liquor washer," a vessel 60 feet long by 12½ feet wide and 7 feet high, fitted internally with a longitudinal partition and serpentine diaphragms, similar to the tar washer, but with a wider single action. The diaphragms are sealed in weak liquor, and the gas, now at a temperature of about 60 degrees, is again drawn through the seal by the exhausters; the diaphragms divide the gas into thin streams, and, in the continuous agitation caused by the displacement, the light tars are washed out and the ammonia is taken up by the liquor. The products pass by a regulating valve into another separator; the ammonia liquor is run into a stock tank for treatment in the sulphate stills, and the light tar, to feed the tar washer.

The exhausters, which come next in the process, are of various forms. There are three of the ordinary Roots blower type, each capable of passing 900,000 cubic feet of gas per hour. As the effective washing of the gas depends on the depth of seal in the washer, the vacuum necessary to draw the gas forward is regulated for each vessel by tubes connected from them to gauges placed in the exhauster house, so that the attendant may control the speed as required.

The second and final liquor washer is placed beyond the exhausters and is the same in all respects as the first, except that the gas is forced through the seal, and the vessel is fed with clean cold water. In this washer the last traces of tar and ammonia are recovered and the gas is cleaned, ready for use at the boilers and air stoves, to which it returns in a pipe, 5 feet in diameter. The products, consisting of weak ammonia liquor, and light frothy tar, are again separated, the liquor is returned to feed the first liquor washer, and the tar, as before, goes to the tar washer.

In the further treatment of the recovered products the heavy tars, run periodically from the bottom of the tar washer into the underground stock tank, are run, as required, into blowers, and delivered by compressed air into an elevated charging tank near the tar stills, into which the tar gravitates for distillation. The tar stills are waggon-shaped boilers, formed with double flue recesses on the bottom, and fired by the clean gas. Each still is supplied with a worm condenser placed in a cold-water tank.

When a still is charged, and the gas turned on and ignited, the first portion of the distillate is water. The tar, as at first recovered from the furnaces, carries about 80 per cent. of water, but this has been reduced, as we have seen, by exposure to the hot gases in the tar washer; when the water has been driven off, a light oil begins to appear, getting heavier as the distillate approaches the pitch stage. The distillate running from the worm passes into a separator; the water, with traces of ammonia in it, is cooled and sent back to feed the first liquor washer, and the oil passes into blowers, whence it is

delivered by compressed air into the oil stock tank, or into barrels for immediate sale. When the still is ready for pitching, the worm is shut off and the liquid pitch is run, first, into a cylindrical cooler, and afterwards into open ponds, where it hardens, and is then broken up, packed, and despatched.

The ammonia liquor, stored in the liquor division of the stock tank, is run into blowers and delivered into an elevated tank as described for the tar, whence it gravitates continuously into the sulphate stills. In the sulphate house there are two vertical cylindrical stills, each fitted internally with 11 horizontal trays having open nozzles projecting upwards, placed as close together as possible, and each nozzle covered by a loose cup with serrated edges. The ammonia liquor is run in upon the top tray, filling all the space round the nozzles and sealing the cups; the liquor is compelled by a baffle plate to circulate round the nozzles and at a certain level runs off by a pipe to the next lower tray, where the process is repeated, and so on, from tray to tray, till the bottom is reached.

At this point steam is introduced under the bottom tray, and passing up by the open nozzles, bubbles out through the serration of the cups; the steam ascending through the nozzles from tray to tray meets the descending liquor, and, by the inducement of greater affinity, robs the liquor of its ammonia, carrying it off at the top in the form of ammonia vapours. These are conveyed by a system of piping into the "saturator," a lead-lined vessel, charged with sulphuric acid; the vapours are taken right to the bottom through a lead cracker pipe, perforated with small holes through which the vapours pass, and combine with the acid, forming ammonia sulphate, which contains 24 per cent. of pure ammonia.

After boiling for some time, crystals of this salt are precipitated on the bottom of the saturator, fished out by hand ladles or mechanical discharges, placed in skips over a draining table, and, when dry, conveyed by an overhead rail to the sulphate store for packing and despatch.

So far, we have been recovering salable products from what was formerly "waste and nuisance," but it cannot be said we have entirely removed the waste or the nuisance. The waste or surplus gas not required for any heating purpose is automatically passed into the atmosphere when the quantity exceeds the pressure required, the escaping gas being burned as it passes into the air.

The waste vapours coming from the saturator may be condensed and purified before passing into the air or destroyed in the still flues and chimney, but the waste or effluent liquor coming from the sulphate still is not so easily got rid of, and the efforts to dispose of it remind one of the tar nuisance of former days. Even after filtration it is not safe to run it into a stream; it seems to be fatal to fish ; at least they do not thrive on it.

At the works referred to in this paper the form of still adopted removes nearly all the solid matter from the liquor. The stills, which are fitted with appliances for ease and rapidity in cleaning, are opened at intervals, and the cups and nozzles cleaned of the pitch deposit. The liquor, as it leaves the bottom of the still, passes into a large settling tank, through which the current travels slowly against baffle plates, throwing down any solid matter. The clean liquor is then run off hot from the top of the tank to feed the steam boiler, where the larger proportion is evaporated in raising steam, and the remainder drawn off from the boilers into a special evaporating pan or furnace, where any remaining solid material is burned down to ash, yielding, on further treatment, a small proporiton of potash.

It is not in the province of this paper to specially follow the various products recovered in the process and their ultimate uses and effects in the industrial arts, but these are not without interest. The pitch oil is extensively used as "light" in factories and large areas by the medium of "Lucigen," "Wells,"

and other lamps and torches, and in enriching poor coal gas. It is also used as fuel in steamers, and under steam boilers and furnaces in other places.

The "pitch" is utilised in many forms. In a thoroughly equipped colliery the coals are washed and screened to various sizes, till the ultimate dust is carried off in the washing as mud. The mud or coal dust is then dried, steamed, and mixed with a proportion of the pitch, and moulded by machines into briquettes. The pitch is also used in all the applications of asphalt for paving, roofing, and felting.

The commercial sulphate of ammonia, besides its numerous chemical applications, is now extensively used as a manure, and holds a prominent place as a fertilising agent. It combines readily with the soil, imparting to it the nitrogen necessary for absorption and assimilation by the roots of plants. It is most widely used in the production of "beet," and as a top and second dressing on grass lands, and generally for the stimulation of all forms of plant life.

It has been said that the world owes much to the man who can make two blades of grass grow where but one grew before, and though hard things have been said about the desolating action of the "coal and iron seeker" in the havoc he has wrought on the earth's surface, still we have seen how even he has done something to bring back a smile to that fair face of nature he has done so much to scar and defile.

He may have done all this for selfish ends, as something to compensate him for the low price of pig iron, but he has paid a debt to nature in practising economy instead of waste of her forces, and fulfilled a duty to society which might be imitated by other coal users on land and sea, for he has made full use of his coal gases, and his chimneys are now restricted to their primary use, that of creating a draught, and not for creating an intolerable nuisance.

A TRIBUTE TO THE LATE FRANCIS AMASA WALKER.

By C. J. H. Woodbury.

BY the death last year of General Francis A. Walker, the president of the Massachusetts Institute of Technology, a career was closed which had been brilliant in action, broad in range, and solid in achievement. A far-reaching life was ended, which had so permeated the thoughts and so influenced the actions of a great many other lives, that they were bereaved in the loss of the source from which much had become assimilated into a part of their being.

There is not the perspective of many years, so essential in most lives, to divest the work from the individuality of the worker, but it is assured that his labours are endowed with that permanency, pictured by Cicero as an inherent ambition of humanity to be equal to all time.

In brief, the record of this eventful life, which began and closed at Boston, where he was born on July 2, 1840, and died on January 4, 1897, may be stated as follows:—He graduated at Amherst in 1860, and entered upon the study of law, which he put aside for its maintenance, by enlisting, in 1861, for service in the American Civil War as a private in the Fifteenth Massachusetts Volunteer Infantry, of which he soon became sergeant-major. Starting immediately upon active campaigning, promotion quickly followed his brilliant services on different battle fields. By successive steps he rose to be lieutenant-colonel. He was adjutant-general of the Second

Army Corps at Fredericksburg and Chancellorsville, where he was so severely wounded as to be obliged to leave the army for a brief period. He was made brigadier general by brevet for gallant conduct at this latter battle, and meritorious services during the war.

With the return of health, he resumed his duties, and participated in the Wilderness and Petersburg campaigns, after which he was taken prisoner and confined in Libby prison, from which he was released by exchange; but so broken in health that he resigned his commission in January, 1865. For the next three years, he was an instructor in Greek and Latin at Williston Seminary, resigning to become one of the editors of the Springfield (Mass.) *Republican*, which position he held for about one year. He then entered the nation's service again, but this time to win his victories on fields of peace.

THE LATE GENERAL FRANCIS A. WALKER.

In 1869, he became chief of the Bureau of Statistics, and two years later was

made Superintendent of the Ninth Census. During a portion of this two-years period, he also held the position of Indian Commissioner. In 1873, he resumed teaching by occupying the chair of political economy and history at Yale College in the Sheffield Scientific School, beginning a term of seven years, which was interrupted by important duties which called for three extended leaves of absence.

The Centennial Exhibition at Philadelphia abounded in enthusiasm and crudity. The lack of a sufficient number of men experienced in administration of large affairs rendered the organisation a tangle of loose ends, which was saved from failure only by the efforts of a few; and Walker was sought, as mankind always seeks leaders, to be chief of the Bureau of Awards, in which position, although only thirty-six years old, he performed the delicate duties of arbiter between eager contestants and indescribable judges, with a finesse and an efficiency worthy of the most astute diplomat.

Two years later, in 1878, his reputation as a political economist had become so well established that he was sent to the International Monetary Conference at Paris as United States Commissioner. The third leave of absence occurred in 1880, when he was called to his old duties at Washington to organise the Tenth Census. While he was at this great work, Professor William B. Rogers, the founder of the Massachusetts Institute of Technology, under the weight of years and impaired health, felt impelled to seek a successor, and most cordially placed his mantle upon the worthy shoulders of General Walker, who entered upon his duties on the first of November, 1881.

His talent for organisation soon began to demonstrate the wisdom of the choice. In sixteen years the number of students increased fourfold, courses of study were perfected, and new ones added, and the confidence of the community was shown by the benefactions of the affluent. "If you seek a monument, look around," not merely at the added buildings, or the apparatus of instruction, but at the living army of those equipped with the results of Institute training who are making two blades of grass grow where one grew before, in the varied technical walks of life where there is no premium on ignorance.

The natural inquiry, after a great man is gone, seeks to analyse the cause of his pre-eminence; but the problem of human life is too complex to be integrated. Nothing succeeds like success, and the inquiry, like a circle, returns upon itself.

General Walker was not a teacher in the pedagogic sense, yet like that ideal teacher, Thomas Hughes, of Rugby, he never forgot that he had been a boy, and was always accessible to any undergraduate, who might well have said, "Here is a court where the time belongs to the suitor." It could not be maintained that he was a scholar of the pedantic standard of one deeply versed in mediæval lore, yet he was always possessed of the facts bearing upon the matter in hand.

He could toil tremendously, and his writings upon political economy show that his mastery of the science had reached out to an assimilated reading of the whole bibliography of the subject. Compare his writings as one may with the brilliant generalisations of others on this subject, there remain in his productions an accuracy of statement and breadth of research which give confidence in his declarations of fact, even if one prefers to make independent deductions.

His writings and addresses on the portions of American war history in which he bore a part, indicate his power of research and faculty for exact statement in graphic phrase which would have established him as firmly as a historian as he was a political economist, had fate so directed. The army experience, added to his college course, gave him, as it did to many other students, wise enough to avail themselves of their opportunities, a post-graduate course in organisation of affairs, and in the discernment of human nature. Master of himself, the man showed his strength in his wisdom to plan and vigour to

execute, selecting competent lieutenants and controlling others without latent irritation.

It is indeed difficult to discriminate between the varied elements of his successful career. He was a brave soldier, but the nation may say with the Spartan ruler, "I have thousands brave as he." His work for the Census could have been done also, perhaps as well, by others. His duties as president of the great technical institute, whose success does not now depend upon the leadership of any one individual, will be performed by others, but as a political economist his prominence was such as to place him in the solitude of greatness.

He was a lover of mankind, and the genial lines of social life were attractive to him. His closest affiliation was with old comrades in arms. He served the city of Boston on the school committee, and the Commonwealth of Massachusetts on the Board of Education. He graced the presidency of the St. Botolph Club, and his last public appearance was at the Alumni dinner of the Institute of Technology the day after Christmas, in 1896, at which he was, it is true, a guest, but "where MacGregor sits, there is the head of the table."

His last days were his best days. Honours were lavished upon him both in his native country and from beyond the sea in recognition of his great services as an organiser of the new technical education, and for his erudition in the science of values.

In the fullness of fame the end came in the midst of his work, without decrepitude, or the tedium of wasting illness, in the manner that the old soldier would, doubtless, have chosen to join the bivouac of the dead.

CHARLES WALLACE HUNT.

A Biographical Sketch.

IT has sometimes been a matter of regret to those who have had occasion to observe the history of engineering in America that there is no method of recognising engineering achievements or success similar to that which exists in monarchical countries, such as Great Britain. In the social organisation of that country with a reigning sovereign at its head, a most graceful custom has prevailed of recognising distinguished service by the honour of a baronetcy, conferred in person by the sovereign and entitling the wearer to an honourable prefix and its accompanying privileges. In the United States a recognition of this sort comes to the statesman and to him who has secured political preferment in the service, either of his city, his commonwealth, or his nation.

To the mechanical engineer, however, recognition rarely comes in any degree commensurate with the service which he has rendered to his community. In this industrial age and amid the more settled surroundings which are the elements of peace and stability in older communities, it is becoming increasingly obvious that the wealth of a community is based largely upon that which the manufacturer brings to it. The opportunity for wage-earnings to a large number; the reduction of cost of manufacture, and the consequent wider spread of purchasing ability; the accumulation of surplus capital in capable hands, and its redistribution in circulation, all are the functions which belong to the successful combination of business man and engineer. The Eastern communities in the United States are not wealthy by reason of their successful agriculture, or their prolific mining interests, but by reason of the well-directed efforts of the manufacturer.

There is an honour, however, which Americans have conferred several times in recent years upon a successful mechanical engineer of this type. The American Society of Mechanical Engineers is a sensitive exponent of the tendencies of the age, and the conferring of its honours upon the manufacturing engineers several times during the period of its history points to the esteem in which they are held under the economic conditions of the present day. It is, doubtless, well known that the American Society of Mechanical Engineers is a national organisation of professional men, drawn from all fields concerned in the industrial achievements of the day, and including many others affiilated with them by congenial tastes and interests. Started in a modest way, it has grown to a membership of over 1800 and is in a position to exert a powerful influence, so that to have office in its ranks is a distinction to be coveted. The honour has fallen upon Mr. Charles Wallace Hunt, of the city of Greater New York, who was chosen to the presidency of the Society at the annual meeting held last December.

In 1872 Mr. Hunt appreciated the opportunity there was for a specialist in the introduction of special machinery for handling ore by mechanical means, and in large quantities, and he has reaped the advantage which comes to many pioneers of being among the first in a comparatively new field on the one hand, while on the other it has been necessary to create machinery and devices without previous precedents or practice to serve as guides. Mr. Hunt's mechanical tendencies, however, have found a wide field and scope in this particular line, and all the details of the present successful business bear the impress of his thought and instinct. Over one hundred patents have been secured and each appliance is the result of a study to meet a definite want, rather than by the inverse method, which seems sometimes to be followed, whereby a conception is elaborated and a place found to apply it as a second step.

Mr. Hunt served as vice-president of the Society of Mechanical Engineers during the two-year term from 1892 to 1894, and has for many years been the chairman of its important Committee on Publication. It was during his term as vice-president that important amendments in the rules and practice of the society, with respect to the qualifications of members, received their definite form.

Besides his connection with the American Society of Mechanical Engineers he is also connected with the Engineers' Club of New York, the New York Chamber of Commerce, the New York Electrical Society, and the American Institute of Mining Engineers. He is, furthermore, president of the Staten Island Chamber of Commerce, vice-president of the Richmond County Savings Bank, and serves as president of several manufacturing companies, both auxiliary to his principal business and independent of it. Mr. Hunt is a man of genial address, of great social tact and affability, and of a commanding, yet winning, presence.

Current Topics.

A SUGGESTIVE illustration of one of the many difficulties from which British employers of labour suffer was afforded not long ago at one large establishment which is extensively engaged in the making of boilers. Electric drilling and boring machines, which assuredly are not novelties in the strict sense of the word, were introduced into the firm's shops for drilling rivet holes, and despatch and economy in work were fondly hoped for by the enterprising manager; but to the men the machines came as revelations of the possibilities of labour curtailment, and they promptly declined to drive rivets in the holes which had been drilled by methods so contrary to those of a sacred past. Argument, persuasion, all were of no avail, and rather than face the never pleasant conditions of a threatened strike, the firm reluctantly withdrew the improved machinery. Increased output and a better quality of work thus were sacrificed to a workingmen's whim. But this is only one of a long list of similar grievances which British employers have to score up against the men, whose interests, after all, are really their masters' interests as well. This, however, they have not yet learned, nor will they learn it except from such dire necessity as the great engineering dispute in Great Britain has brought upon them.

APROPOS of this unfortunate industrial disturbance, a story comes to mind of a certain firm in Sunderland who, some years back, had contracted for some ship repairs at a stipulated price, and, to this end, had previously agreed with their men,—Members of the Boiler Makers' Society,—upon a certain scale of wages to be paid for the job. When the work, however, was about to be commenced the men decided that they would strike for more pay, regardless of the fact that such increased pay would not only deprive their employers of whatever profit might have been in the job, but would entail a direct and serious loss to them. Finding argument with the men useless, the firm laid the case before Mr. Knight, the secretary of the union, and he promptly advised them to give in to the demands of the men, pay them all that they asked for, and then send to him the bill for the difference. This was done, and in due course the firm received a check from Mr. Knight for the sum that they had paid beyond the agreed price, and the Sunderland branch of the Boiler

Makers' Society was subsequently assessed for the amount involved. The whole thing was a very effective method of disposal of what might have become a serious difficulty.

THE far western part of the United States,—that is, the part west of the Missouri River,—is a country full of enterprise. Fancy a Russian, or even a German or British town of 1500 inhabitants, ordering an electric light plant which would have to be hauled over mountainous bridle paths for 150 miles from the nearest railway station before it reached its destination! Yet this is what the town of Lander, in Wyoming, had the courage to do, each mule employed taking twelve days to make the round trip between Bitter Creek, on the Union Pacific Railway, and the town whose progress was apparently impeded for want of the latest and most expensive means of artificial illumination. The town of Sheridan, also in Wyoming, had only 600 inhabitants and was 200 miles from the nearest railroad when it discovered that an electric light plant was essential to a continuance of its self-respect. Accordingly the plant, packed in very small pieces, was hauled 200 miles and Sheridan was happy. Since then this town has had a streak of luck, for the Burlington Railway, pushing its way toward the Yellowstone river, has gone right through it, thereby increasing its population at a single bound from 600 to 1000. Buffalo, another town in the same State, having 600 inhabitants, thought 44 miles a comparatively short distance to haul its electric light plant.

IN the adjoining State of Idaho the important town of Lewiston, with 2000 inhabitants, had its electric light plant hauled on boats for 80 miles up the Snake river. Murray, with 700 population, had a 60-mile overland passage to accomplish, or about the same length that Silver City, with a hundred less population, hauled its electric light plant. Turning now to places situated on the railways it is found that Newcastle, Cambria, Rawlins, Rock Spring, Green River, and Evanston, in Wyoming, and Pocatello and Idaho Falls, in Idaho, have each an electric light plant, though the population of not a single one of these towns exceeds 300. Boise City, Idaho, as befits a town puffed up with 8000 inhabitants, has not only an electric light plant, but a system of trolley cars. Moreover, as some natural hot springs happen to be close to Boise City, the citizens heat their houses with the hot water from them, and even raise early spring vegetables by using the hot springs for irrigation purposes The three small mining camps of Cœur D'Alene, Wallace and Wardner use electricity for lighting purposes all the year around, while their available water power is used to run the mills for stamping ore. But in winter when the main water supply is frozen, the electric current is connected with the stamping mills and lighting and power is furnished by a lavish expenditure on coal at $10 a ton.

THE recently published report of the chief of the Bureau of Construction and Repair of the United States Navy Department derives particular interest from the fact that it gives some of the results of using electricity for moving the turrets of war ships, though it has long been known in a general way that in delicacy of movement, in rapidity of starting, and in certainty of action, electricity is far superior to either steam, compressed air or hydraulic power,—the other forms of motive power used for this purpose. One great drawback to hydraulic machinery is its tendency to freeze up in cold climates, which, of course, at once destroys its efficiency. Steam, on the other hand, while free from the defect of freezing, must always take a certain, perceptible amount of time to overcome the inertia of the piston and its attached machinery. Moreover, this inertia, once overcome, requires an equal force to bring the machinery to rest again. Thus, it is found

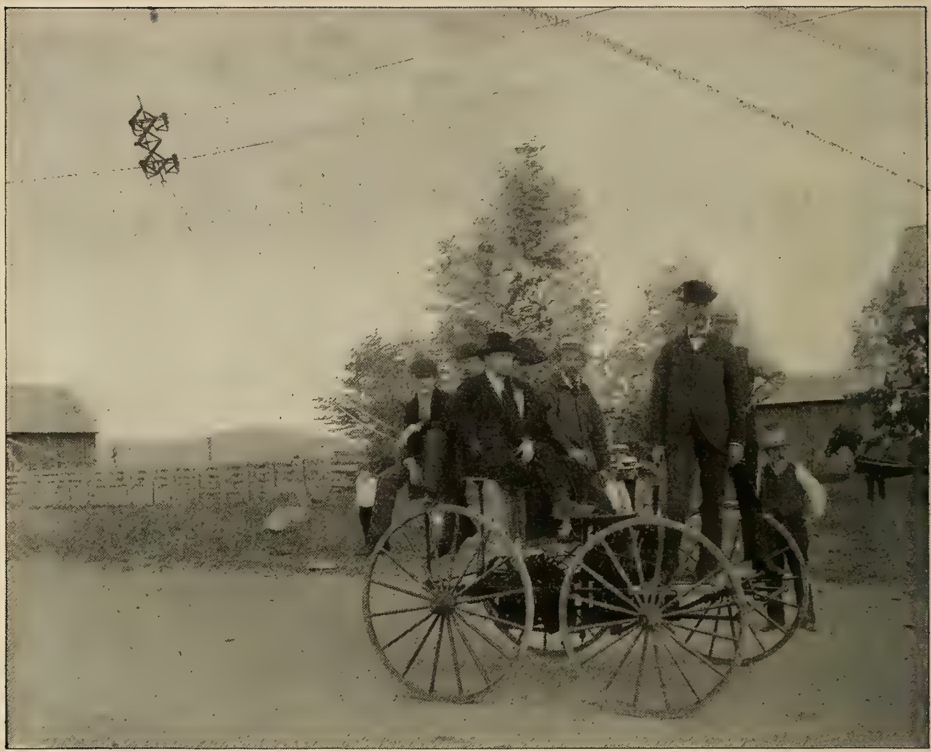
that with a turret 15 feet in diameter the least movement possible with steam machinery, calculated on the rim of the turret, is 4 inches, while actual tests on one of the war ships of the United States several months ago showed that with electric turning gear a turret of the same diameter, could be moved—that is, started and stopped again—twenty-nine times in one inch. The proportion between steam and electricity, therefore, in delicacy of movement in this instance is four times 29, or 116 times as great. The chief objection to all radical innovations like this one has hereto been based on the sound principle that in actual conflict the machinery or motive power might break down and the work would have to be done by hand power in such an emergency; thus guns, turrets and every other fighting appliance on board some war ships are provided with alternative hand tackle. But there does not seem to be any reason why electricity would not lend itself to be coupled with hand power apparatus, at least as well, if not better, than either steam or hydraulic power.

THERE have been mountain railways galore within the past few years, but none quite so novel, in point of motive power at least, as the one which is reported to be ready shortly for traffic up the Hochstauffen, near Bad Reichenhall, in Germany, and of which a sketch is given on this page. The illustration appeared originally in the *Illustrierte Zeitung*, a German publication, and in this also were given also some of the particulars which are here reproduced. The immediately striking feature of the enterprise is found in the fact that a balloon furnishes the operating power for the up-trip, the grade evidently being sufficiently steep to have suggested the possibility of such an arrangement. A single rail directs the course of the train and keeps the balloon with its load captive, being I-shaped to this end, the car gripping it at the sides and underneath the top flange. At about every 15 feet the rail is firmly anchored. In descending the mountain, gravity is the propelling force, and water ballast, taken aboard at the upper end of the line, helps to overcome the upward pull of the balloon. A cock on the water tank on the car can be opened by the operator at any time. The tank can carry about 1100 pounds of water, and the car and tank together weigh about 600 pounds, while the balloon, which is

A BALLOON RAILWAY.

67 feet in diameter, is said to have a lifting capacity of somewhat over ten thousand pounds. Weights also can be taken aboard or discharged at the several stations along the line and thus afford additional means of regulation. As a novelty certainly the whole outfit ought to be satisfying to those who are on the lookout for such things, but how the thing will work, that "is another story."

AN electric trolley waggon for country roads, which is suggestive of a num-



AN ELECTRIC TROLLEY WAGGON FOR COUNTRY ROADS.

ber of interesting possibilities, has been built and successfully operated in the United States by Mr. W. G. Caffrey, of Reno, Nevada. As generally descriptive, probably nothing would afford a better idea of the nature of the vehicle and its accessories than the illustration on this page, which has been reproduced from a photograph kindly supplied by Mr. Caffrey, and which represents his waggon working along a short experimental line which he had put up specially for the purpose. The system involves the use of a double trolley arrangement, and the two wires are run about 18 inches apart, and 17 feet above the ground. The trolley device proper consists of a metal frame with two overrunning trolley wheels, having locking wheels underneath, which prevent the top wheels from leaving the wire and still do not obstruct the free passage of the frame over the supports on the poles. On the lower wire a similar device is used, and both sets of trolley wheels are connected by an insulated pantograph arrangement which effectively provides for unequal tension on the trolley wires. Connection between the trolleys and the waggon is made by cables, which run on an automatic reel on the waggon. This permits the cables to run out a few hundred feet, if necessary, or winds them up to a short length, and the waggon thus has considerable freedom in direction of travel, enabling it to readily turn out of the way of obstacles and to follow twists and turns of the road without difficulty even though the pole line may take a somewhat different and possibly more convenient course. A two horse-power motor on the waggon is geared to the rear axle for propelling effect. For traction on common roads,—for the transportation of farm produce, for example, in places removed from railway facilities, which is becoming a matter of growing importance,—Mr. Caffrey's proposition prompts interesting speculation, and as

a possible competitor of the light railway it is worth studying.

In a series of articles on aluminium, recently printed in *The Engineer*, of London, reference was made, among other things, to the seriously objectionable influence of sodium on the other metal. Sodium is said to be often irregularly disseminated throughout the mass of aluminium, and, therefore, comparatively large amounts may occur in one spot. It is oxidised almost as quickly by damp air as by water itself, and the product of the reaction,—caustic soda,—is one of the most powerful solvents of aluminium. Indeed, the regular impurities of commercial aluminium may be divided into two classes, according to their harmfulness,—sodium in the first, and all the others in the second. Still, great progress has most certainly been made during the past few years towards the production of a pure metal, and at the present day, if due care be taken to select only the best varieties, or, in case of doubt, to have it subjected to a careful analysis before use, and to employ it for purposes to which it is really adapted, there need be little fear of unpleasant consequences. A good idea of the way in which aluminium lends itself to practical work was given by a bed plate of this metal for an engine and a dynamo cast some time ago by Messrs. W. Mills & Co., of Sunderland, and exhibited by them at the Yachting and Fisheries Exhibition last year. This bed plate showed with what facility suitable aluminium alloys may be cast, even in complicated moulds, and afforded an admirable answer to any doubts about the useful application of such alloys to commercial purposes.

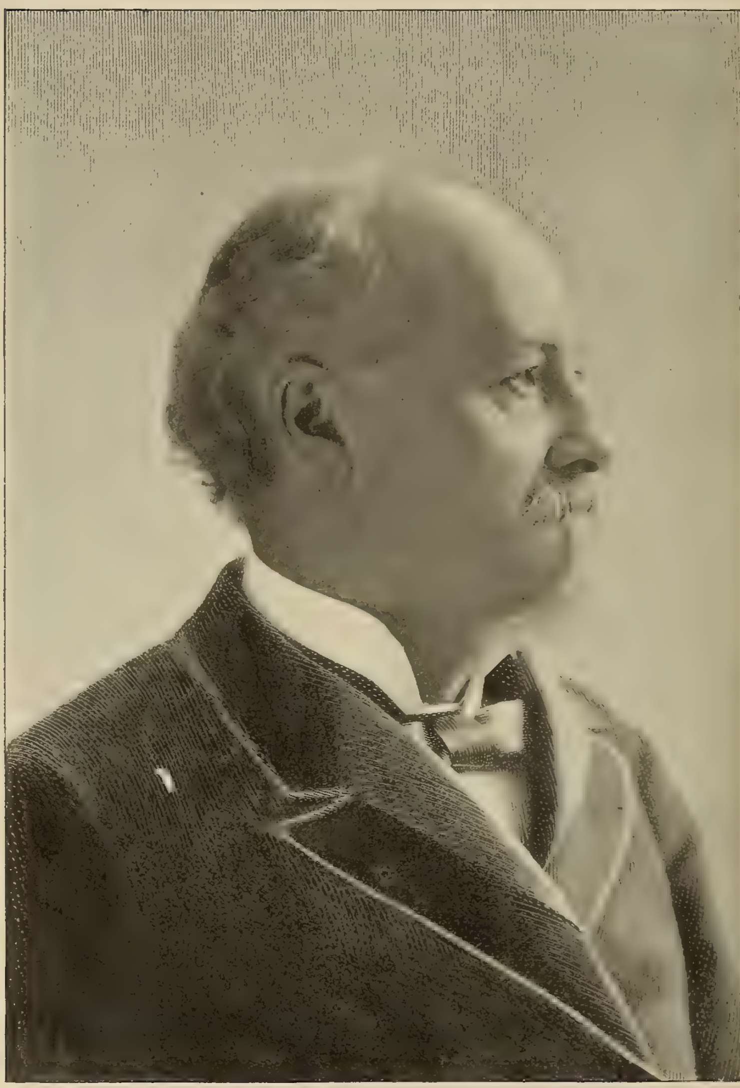
Some time last year there occurred in London a horrible accident at a hairdresser's establishment through the ignition of an inflammable lotion while being applied to a woman's hair. From all the evidence obtainable at the time it was a clear case of ignition by an electric spark, produced by the friction of the hairdresser's hand on his patron's hair, and furnished an instructive lesson of the grave dangers which are apt to creep, unsuspected, into every-day operations. Lord Kelvin, referring to the subject in the London *Times* shortly after the accident, spoke warningly of the readiness with which combustible gas and air mixtures are ignited by even very faint electric sparks. "This readiness to ignite," he remarked, among other things, "is illustrated in elementary lectures on electricity by Volta's cannon — a little varnished brass gun, mounted on a glass pillar, and having a wide touch-hole plugged with sealing wax, in the centre of which is mounted a brass wire carrying a little brass knob outside, and projecting inside to within one-twentieth of an inch of the end of another brass wire fixed to the metal of the gun. The gun is filled with an explosive mixture of oxygen and hydrogen, and its muzzle is plugged with a cork. The varnished outside is struck with a piece of catskin, and, thus electrified, the gun is left insulated on its glass pillar. To fire it, all that is necessary is to touch the projecting knob with the finger. This causes discharge of the electricity by two exceedingly faint sparks, one barely, if at all, perceptible by the finger before contact with the knob outside, the other in the one-twentieth of an inch air space within the explosive mixture inside. A loud explosion is heard, and the cork is projected with sufficient violence to tear a canvas picture if it chances to touch one."

Ignition of vapour of benzine by an electric spark, Lord Kelvin went on to say, is well known to dyers in their process for cleaning silks and other fabrics by boiling in large cauldrons of liquid benzine. When the goods are taken out of the cauldron and spread out to dry on a table, explosions have often taken place, and there can be little question that an electric spark, caused by some slight friction between

dried or partially dried portions of the fabrics, is the incendiary. We all know how readily electric sparks, visible in the dark, and perceptible to the ear by slight crackling sound, are produced by drawing a hand over very dry hair, or the teeth of a comb through it. During the inquest after the accident previously mentioned it was stated that the merit of the hair wash was that it dried so readily. The hair-dresser said he felt the hair warm in his hand, and immediately after that all was envelloped in flame. The fact that the hair seemed warm to the hand was, however, not due to the beginning of some kind of spontaneous combustion; it showed merely that the part of the hair touched had quickly become dry. Very light friction of the hand on the dry hair would suffice to produce an electric spark; and the explosive atmosphere of air mixed with combustible vapour, from the portions of the hair not yet dry, was there.

REFERRING to the item recently printed in these pages concerning the origin of the terms "starboard" and "port", a correspondent has made the point that the former term has been in use in the English language from a remote period, occurring in Anglo-Saxon as "stear-board", and in middle-English as "stereboard", while in later times it was written "sterboard", from which it developed into its modern form "starboard." It originally meant, so our correspondent says, the board, or side, of the ship on which the man who *steered* it was placed. It may be called a native English word as distinguished from one of imported origin, and it possesses a special interest in its indication of the method of propelling and steering in vogue from very early times. The ancient mariner could run before the wind with his single square sail, but he could deviate only a few points on either side. Unless therefore the direction of the wind agreed with the course of the vessel, it was necessary for him to be in constant readiness to modify his direction by the help of the oar.

THE illustrations of early English manuscripts and the later figures of tapestries exemplify the old square rig, with auxiliary oars and steering from the side. In these examples one or more heavy oars are used at the bow and on one side only; whilst the course is kept by a steersman with a lighter, and often paddle-shaped, oar, worked near the stern, and invariably on the starboard side of the ship. This method of rowing survived until quite recent times, and was well shown on the coal "keels", which added so picturesque a feature to the navigation of the river Tyne. These vessels were manned by crews consisting of three men and a boy; they had a single square sail, and carried some twenty-odd tons of coal. When unable to run before the wind, resort was had to rowing, and this was done by a single heavy bow oar, worked on the port side by two men and a boy, whilst the skipper kept the course, rowing in time with a lighter oar, called a "swape", from the stern on the starboard side. The fixed rudder, hinged from the stern-post and operated by a tiller, was a later development in ship construction. The Tyne "keel" exemplifies the earlier practice of our ancestors in steering by an oar from the right side of the ship, and from this comes the designation for that side as the "steer-side", or starboard.



O. Chanute.

PAST PRESIDENT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

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LIQUID FUEL FOR LOCOMOTIVES.

By A. Morton Bell, Great Eastern Railway Locomotive Department.

THE adoption of oil firing locomotives has occupied the attention of engineers and inventors for many years, and the archives of the Patent Office abound with numerous practical and impracticable schemes for the purpose. The majority of those coming under the former heading relate to different forms of spraying appliances by which the oil fuel is "injected" and "atomised" by steam or air jets in a suitable furnace; those of the latter class include attempts to gasify the oil, before burning, in complicated retorts, and pipes feeding the oil into trays and grooves in the grate or supporting combustion by means of fireproof wicks.

The apparatus proposed by an Italian inventor is perhaps the wildest of all; he intended to place a series of rollers along the bottom of the furnace, having "paddles" or floats attached, with asbestos wicks hanging from them. These were to dip into the ashpan which formed a tank of oil, kept filled to a certain level from the tender. The rollers were to be kept slowly revolving by chain gear from the driving axle of the engine, and as the wicks came to the upper side, charged with oil, they were supposed to ignite and burn.

The earliest experiments with oil fuel on locomotives were probably those of Mr. Brydges Adams, in the United States, as far back as 1863, but particulars of the arrangements which he made and the results which he obtained appear to be wanting, and we must turn to France for the first reliable information on the running of oil-fired locomotives. M. Sainte Claire Deville conducted some exhaustive trials during 1868-9, and had two engines working regularly on the Eastern Railway in 1870. These had inclined grates arranged in the fireboxes and the oil fuel was allowed to "trickle" along grooves on the upper edges of the bars forming the grates. Combustion was supported by air drawn in from the ashpan through the spaces between the bars, in a way similar to that required for coal, by the action of the blast. One of these engines had 18-inch cylinders and it consumed on an average 19 pounds of oil fuel per mile run, which was not an extravagant figure if the trains hauled were of reasonable weight, and considering the crude arrangements adopted for distributing the oil. Eleven pounds

THE CROMER EXPRESS ON THE GREAT EASTERN RAILWAY. ENGLAND, STARTING OUT.

of water were evaporated per pound of oil fuel, against 7.9 pounds per pound of good briquette on similar engines.

Notwithstanding the success attending the running of these engines, the adoption of oil fuel for locomotives did not extend in France owing to the prohibitive price of suitable oils at that time. It would seem but natural, after all, that the general substitution of liquid for solid fuel would be more easily accomplished in a country where oil is plentiful and cheap, and coal or wood scarce and expensive, than in one where the oil must necessarily be an imported commodity.

Until recent years the desired conditions could be said to exist only in South Russia, for that country, although abundantly supplied with petroleum, has neither coal nor wood available for fuel, whereas in the United States, for example, the immense oil deposits of Pennsylvania and Ohio are in close proximity to similar wealth in coal, which effectually checks the use of oil fuel on the score of economy in that region. Lately, however, the opening up of the oil fields of Southern California has led to the use of liquid fuel on an extensive scale there, and the discoveries of petroleum in Chili, Peru and Argentina have caused oil to be used largely on locomotives in those countries. Coming back to Europe, Galicia now provides a large source of supply; and in Asia, Sumatra, Burmah and India all have their oil-burning engines.

In 1874 Mr. Urquhart, the locomotive superintendent of the Graizi Tsaritzin Railway, in South Russia, tried oil fuel for some of the engines under his charge, and the experiments being successful and the supply of oil residues becoming plentiful, solid fuel was gradually supplanted with liquid on that road, and in 1885, when the whole of the engines (143) were using petroleum fuel, the consumption was given as follows:—

On eight-wheeled engines, 45.83 pounds of petroleum per mile, costing 6½d.
On six-wheeled engines, 32.23 pounds of petroleum per mile, costing 4½d.

This compares very favourably with the following figures for coal during the year 1862 when that fuel was employed:

On eight-wheeled engines, 81.43 pounds of coal per mile, costing 11½d.
On six-wheeled engines, 57.25 pounds of coal per mile, costing 7¾d.

In 1878 a locomotive on the Long Island Railway, in the United States, was fitted to burn oil, and, again, in 1888, some elaborate trials were made on a locomotive engine at Alexandria, Va., United States, for the guidance of

the United States Navy. In this instance the burner or atomiser was supplied with both superheated steam and hot compressed air, and the oil was fed under pressure. It appears to have been of a complicated character, for it had no less than 124 nozzles and was placed on a plate facing the fire door. The evaporation of water from and at 212° F. is stated to have been 16.9 pounds per pound of petroleum which had a theoretical efficiency of 21.75 pounds by actual analysis. From this it appears that over 75 per cent. of the total heating power of the oil was utilised, which is a much larger proportion than that usually secured from a coal fire.

In Great Britain, on the London, Brighton and South Coast Railway, a four-wheel coupled passenger tank engine was fitted in 1886 to burn oil on a system patented by Messrs. Tarbutt & Quentin. It ran during the months of June, July and August of that year, but apparently was not very economical in consumption when compared with its own performances with coal, for during the three months' running 24.3 pounds of oil were burnt per mile, against 18.27 pounds of Welsh coal. The evaporation of water per pound of oil was 9.65 pounds and per pound of coal 8.88 pounds, the temperature of the feed being approximately 130° F. From these figures it seems that the largely increased output of steam from the boiler if not used by the engine must have been taken to work the oil burners; hence, the increased consumption of a fuel which gave a higher evaporation than coal.

Had this engine been entirely successful, however, both on grounds of efficiency and economy, it is still doubtful if a British railway company would be justified in converting engines from coal to oil in face of the keen competition which would necessarily ensue between the two fuel markets. This line of argument was taken by Mr. James Holden, the locomotive superintendent of the Great Eastern Railway, when, about the same time as the above men-

UNDER WAY.

tioned experiment was taking place, he commenced utilising as fuel the waste tar products from the compressed oil gas works at Stratford. For this purpose he devised a burner which, whilst effectually spraying and distributing the oil fuel, also provides air for combustion independently of that admitted through the ordinary dampers. By this means it becomes possible to apply an apparatus to existing furnaces without alteration or the provision of additional firebrick constructions, enabling oil to be used in conjunction with the ordinary coal fire.

The preliminary trials under a stationary multitubular boiler proved so satisfactory that one of the improved burners was fitted to a six-wheel coupled shunting tank engine, which made a number of experimental runs between Stratford and Broxbourne during the closing months of 1886. From these considerable experience was gained, and many improvements were effected in the arrangement of the apparatus to make it conform to the every-day requirements of a railway locomotive.

This engine, No. 281, is still doing good service in the yard at Stratford. It has one burner only, placed centrally on the firebox front just below the footplate, about eighteen inches above the firebars. The firebox is provided with a brick arch in the same position as that on all the coal-burning engines of the Great Eastern Railway, and there are tanks in the coal bunker holding 200 gallons of oil fuel.

After trials on the above-mentioned engine a four-wheel coupled passenger tank engine was fitted for burning oil fuel and put into service. Four burners were at first used, two at the front and two at the rear of the firebox, and the opposing sprays were expected to give a much better result than was actually attained, for, although the consumption of oil was comparatively large, the engine never steamed well, and, further, the number of valves and pipes were objectionable. After a few runs, the two burners at the tube-plate end of the firebox were removed and the holes blocked up; this greatly improved the engine's steaming capabilities.

Superheated steam and compressed air were both tried, but although a somewhat brighter fire and a slight economy of fuel were secured, the disadvantages in the way of pipes and fittings for the former and compressing pump for the latter more than discounted any advantage. One great de-

A FOUR-COUPLED EXPRESS ENGINE ON THE GREAT EASTERN RAILWAY, BURNING OIL FUEL

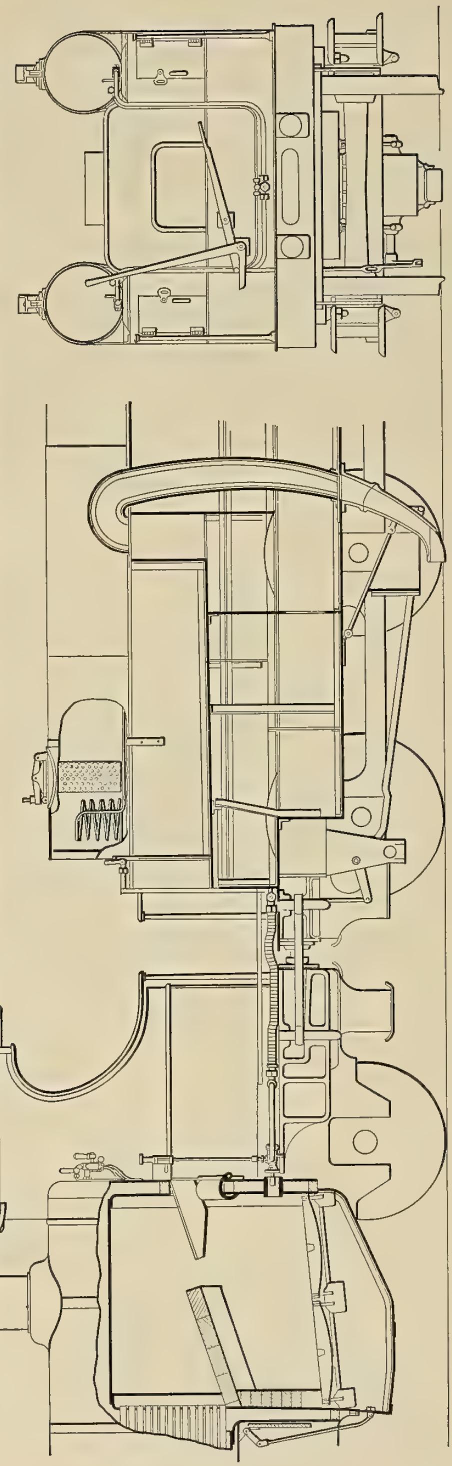
A VIEW IN A CALIFORNIA OIL WELL DISTRICT.

fect was soon detected in the arrangement of the burners on this second locomotive; they were placed too high above the firebars, and when oil was being burnt above the coal fire, the combustion of which was curtailed by partially closing the dampers, it was tantamount to raising a second fire among the products of combustion from the lower one, a proceeding which caused a great noise and gave but a poor return. Nevertheless, with all its defects, this engine ran regularly in the suburban passenger service for several months and did some excellent work.

The next locomotives fitted on the Great Eastern Railway had the burners placed as near the level of the firebars as it was possible to get them, after allowing for a base of hot fire or incombustible material, so that all combustion, whether of oil or coal, took place at practically the same plane.

The standard arrangement of apparatus now adopted is shown in the drawings, on pages 376 and 378, of one of the Great Eastern single-driver express engines. From these it will be seen that two burners are provided, injecting the fuel through apertures made in the firebox about twelve inches above the bars. The oil and the steam for injecting and spraying it are led to the burners through pipes and suitable connections arranged on the foot-plate below the boarding on which the enginemen stand. The tanks carrying the oil are placed on the tender, lengthwise, to equally distribute the weight over all the axles. The total capacity is 650 gallons, and the attachments are such that these tanks are quite self-contained and entirely independent of the tender, so that in the event of a derailment they would fall clear of the engine. A steam warming coil is provided in each tank, so that the contents may be rendered sufficiently fluid in cold weather to enable the supply to the burners to be accurately regulated. Shown in dotted lines in the cut on page 378 is a heating arrangement by which the air brought into the furnace through the central annular steam jets of the burners is heated to a high temperature by the waste gases of the smoke box.

The construction of the latest pattern of the Holden burner for locomotives is shown in the illustration on page 379. The steam inlets are marked *X* and *Z*, and the oil connection is marked *Y*. The steam entering at *X* is conducted to a central annular cone having an air passage through its centre. All three, steam, oil and hot air, are then pro-



HOLDEN'S LIQUID FUEL BURNING APPARATUS ON A STANDARD SINGLE EXPRESS LOCOMOTIVE OF THE GREAT EASTERN RAILWAY.

jected through the front nozzle in semi-sprayed jets, which are there met by the small angular jets and the parallel ones of the ring blower fed with steam from the connection, *Z*. The complete atomisation of the fuel is here accomplished, and, as, at the same time, atmospheric air is forced into the furnace by the action of the blower jets, very perfect combustion is ensured and also a good distribution of the resultant heat over the furnace. In case the cones become blocked or damaged, the whole interior can be easily removed and replaced with a new set by unscrewing the large hexagonal nut which secures the cones in proper position in the outer case.

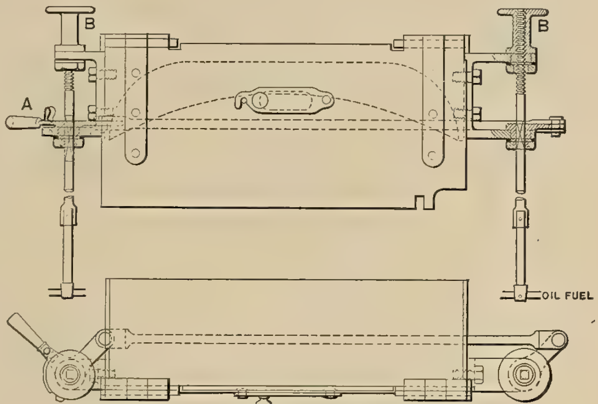
A coupling is shown at the rear of the burner by which a flexible hose pipe can make connection with the hot air pipes from the heaters in the smoke box, already mentioned; or through this, if desired, the exhausting of the central jets can be utilised to maintain the continuous vacuum requisite for the working of the automatic vacuum brake along the train, thus saving the steam usually blown away by the small ejector provided for this purpose. The ball valve which is shown prevents any return of oil or steam along the pipes when the large ejector is applied for rapidly creating a vacuum after a stop.

The two burners receive their steam in unison from a fitting, fed with dry steam from the dome and placed on the firebox front. This has four cocks, one to control the steam admitted to the central jets of the burners; another for that supplied to the ring blowers; a third to act as a "blow back" or cleansing jet of steam which is conducted into the main oil pipes, and a fourth for the steam heaters in the fuel tanks on the tender.

For the adjustment of the oil fuel supply to the burners a novel arrangement of combined cocks and valves has been introduced, for it must be remembered that a very different cycle of events is apt to occur on an oil-burning locomotive as compared with a coal-burning one. When the regulator is shut, the blast of the engine ceases and

the draft with it, with the natural consequence that the rapid combustion of the coal fire is automatically curtailed, whereas when liquid fuel is being used the same quantity of oil might be injected into the furnace when the draft is *nil* as when it is at its maximum, for the steam at the burners will continue spraying it in unless the supply is decreased at the controlling valves. This, too, must be done quickly when the regulator is suddenly closed, or a far too rapid generation of steam will ensue as well as emission of smoke.

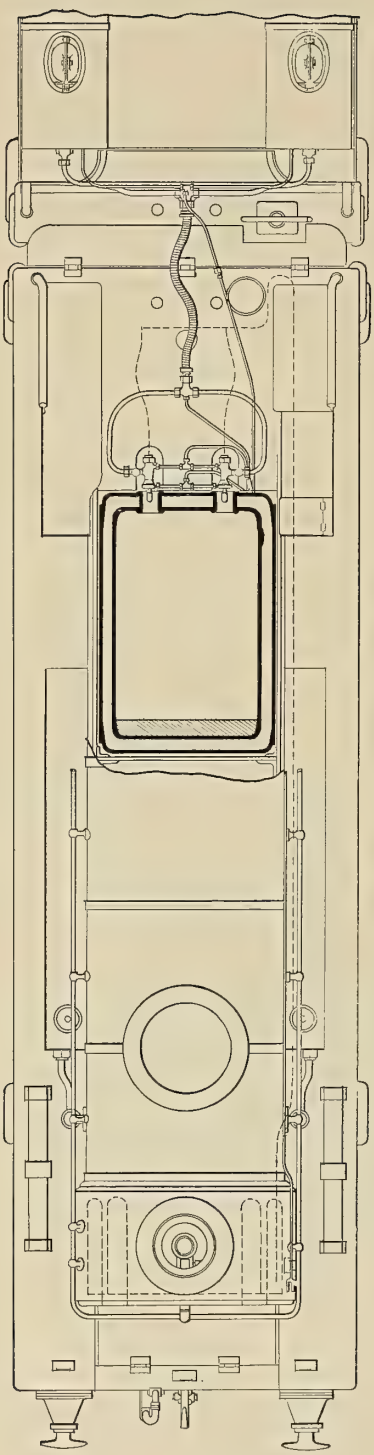
The front guard or shield placed over the fire door is shown in the drawing on this page, with the gear for operating the oil fuel valves attached. The horizontal handle *A*, has a connecting rod attached by which the nuts or sleeves working on the square portions of the two vertical spindles, operating the valves, can be partially revolved simultaneously to open or shut the small passages through the plugs to the oil supply. For an accurate adjustment the plugs can be independently raised or lowered by the milled heads *B B*. It will be seen from this that oil is admitted to the burners by turning the plugs and by raising them.



THE ARRANGEMENT OF THE OIL VALVES.

In practice, the fire is started by the former movement, the passages through the plugs being of such a limited size that only a small quantity of oil can pass, sufficient for burning when the engine is standing without blast. When running, the amount can be augmented to meet requirements by the second oper-


A SUBURBAN PASSENGER TANK LOCOMOTIVE ON THE GREAT EASTERN RAILWAY, FIRED WITH OIL FUEL.



PLAN OF GREAT EASTERN RAILWAY OIL-BURNING LOCOMOTIVE, SHOWING PIPES FOR CARRYING HEATED AIR TO THE FURNACE.

ation of raising the valves, which will porbably mean an additional fifty per cent. If, now, the regulator of the engine is suddenly closed, a quarter turn of the horizontal handle to the " shut " position will instantly cut off half the supply to the burners.

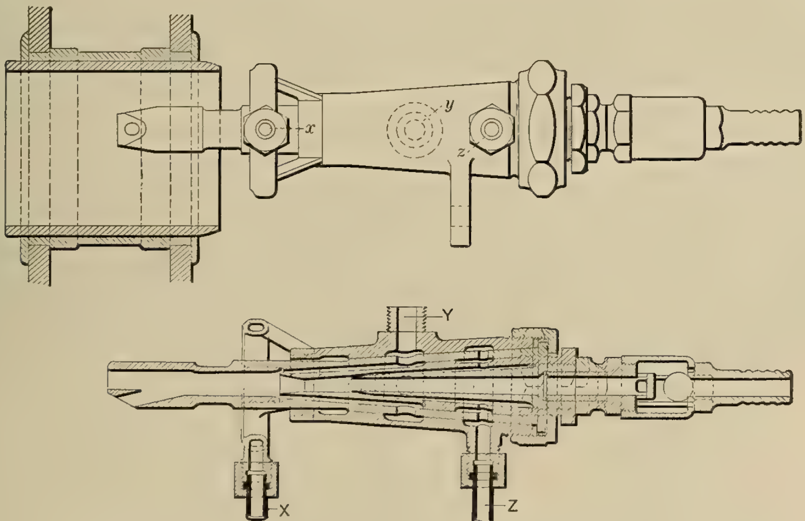
There are thirty-seven oil-burning engines now running on the Great Eastern Railway; twenty of these are passenger tank engines of similar design to the one shown on page 377, and they are chiefly employed in the London suburban district; fifteen are express engines, of which the one on page 374 is an example; one is a six-coupled goods engine, and the last is a six-coupled shunting tank engine, already mentioned.

The suburban engines are worked on combined fuels, that is, a coal fire is maintained on the grate and the oil fuel is injected and burned above it. This is found to be a convenient system of working for these engines on account of the constant stopping and starting. Their consumption in daily service is 17.8 pounds of coal and 10.7 pounds of oil per mile, against 40.4 pounds of coal when fired with this only.

The express engines are of two classes, single drivers and four wheels coupled, but the chief dimensions are precisely the same, viz., drivers, 7 feet diameter, and cylinders, 18 inches in diameter by 24 inches stroke. The grate area is 18 square feet and the working pressures are 140 and 160 pounds per square inch. Both systems of working are in vogue on these engines, viz., coal and oil combined, and oil entirely, and with the express trains of the summer season of 1897 the relative consumption has been:—Coal, 10.5 pounds per mile, and oil, 11.4 pounds per mile; or a total of 22.9 pounds, including fuel used for lighting fires, against a consumption of coal only of 34 pounds per mile.

On one of the four-wheel coupled express engines, having $2\frac{1}{4}$-inch Serve tubes in the boiler and burning oil exclusively, 16 pounds per mile sufficed for the running, but this does not include a wood fire for a start.

During July, August and September the single-driver express engines worked regularly the special Cromer express, making the run from London to North Galsham, 130 miles, without a stop, in 160 minutes. This train was booked to consist of 10 carriages, but usually had additional vehicles. Its load is 180 tons, excluding engine and tender, and it had to be hauled over a heavy road abounding in obstacles to fast running.



HOLDEN'S COMBINED LIQUID FUEL INJECTOR AND AIR EJECTOR.

Numerous junctions forbid a high rate of speed for the first few miles, and before the train is well under way Brentwood bank, averaging 1 in 100, has to be overcome; then come several slacks at important stations, dips into two water troughs to fill the tender, and almost a stop at the Norwich swing bridge to pick up and set down a pilot man. Single - line running commences at Wroxham, necessitating exchange of train tablets at the crossing stations, and the trip winds up with a stiff pull up an incline of 1 in 100 to Cromer. About 180 gallons of liquid fuel made the average consumption for the run, which was, without exception, the fastest and longest in the world for a train worked by an oil-fired engine. On arrival a few pieces of wood or a shovel or two of coal would keep sufficient fire to relight the oil when required for return running.

For the storage and supply of the oil fuel a large depot is now in use at Stratford, and smaller reservoirs are provided at Ipswich and Norwich. That at Stratford, shown on page 382 is a good example of what is necessary for an installation in Great Britain. The oil fuel on arrival is emptied from the tank cars into a series of underground storage tanks with a total capacity of 50,000 gallons. From these it is pumped by a rotary pump through 3-inch mains to high-level cylindrical reservoirs, holding 40,000 gallons. The engine tanks are filled from the crane arms through 4-inch pipes, the flow being controlled by sluice valves at the extreme ends of the arms. As the storage is located near large stores of coal and timber, the tanks are completely isolated by a circular embankment, 4 feet high, and a water course around it, 10 feet wide, access being possible only by a small foot-bridge.

Various grades of oil have been dealt with here, ranging from refined petroleum for gas making to ordinary coal gas tar for burning. This latter represents the easiest procurable and cheapest material obtainable at present for

AN OIL-FIRED LOCOMOTIVE ON THE AUSTRIAN STATE RAILWAY FOR SERVICE IN THE ARLBERG TUNNEL.

liquid fuel, and although the fire raised by it is not to be compared with that from petroleum residue for intensity and clearness, still it answers well on locomotives where a good draft is maintained. Astatki, or residue, the liquid fuel burner's great desideratum, has been used on the Great Eastern Railway, and when the supply of this product in large quantities has been properly organised, it will, no doubt, again become the chosen fuel.

With petroleum residue having a specific gravity of 0.89, and a theoretical efficiency of 22,000 heat units, an evaporation of 14 pounds of water per pound of the fuel has been obtained against 8 pounds per pound of good coal. Add to these figures the economy which can be introduced on an oil-fuel engine by the perfect control of the fire to meet demands for steam, and the maintenance of an equal heat in the firebox, due to the possibility of running for long intervals without opening the fire door, and we have the range of practical efficiency raised to double that of coal. On an experiment running over four months, with two express engines burning oil fuel and two identical engines burning coal, the comparative consumption was as 1 for oil to 2.125 for coal.

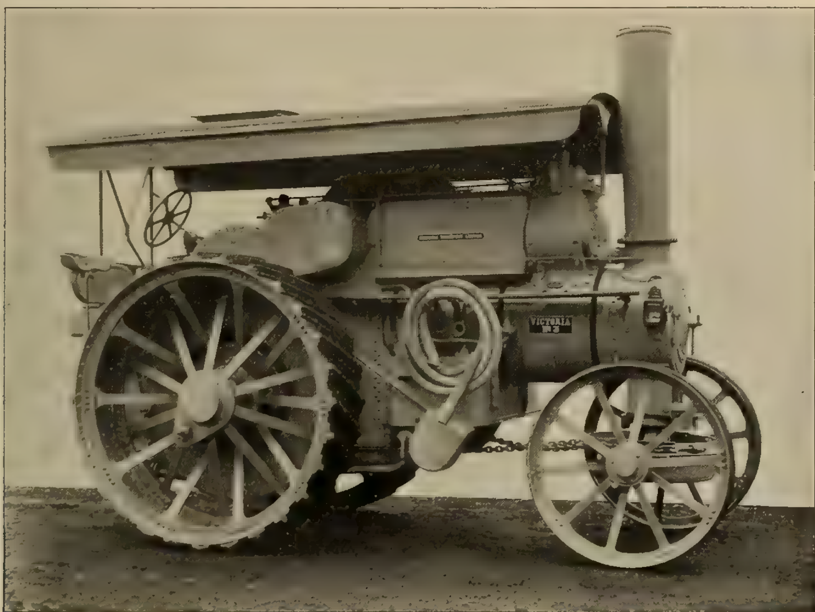
In countries where oil fuel is cheap and coal or wood expensive, the Holden apparatus has been largely adopted, as hinted at the commencement of this article. In the United States the Los Angeles Terminal Railroad in California has its engines fired exclusively with petroleum, and excellent results have been recorded in its favour, as the following figures amply prove.

With Los Angeles oil costing 75 cents per barrel, the cost per mile has been 11.1 cents, against an average for the year immediately prior to the adoption of oil fuel, of 28.3 cents for coal. This

shows a saving of over 60 per cent. in the fuel bill. These engines stand all night in the shed with dampers closed and a cover over the chimney, and have 20 to 30 pounds steam pressure in the morning ready to light up the oil fire again without coal or wood.

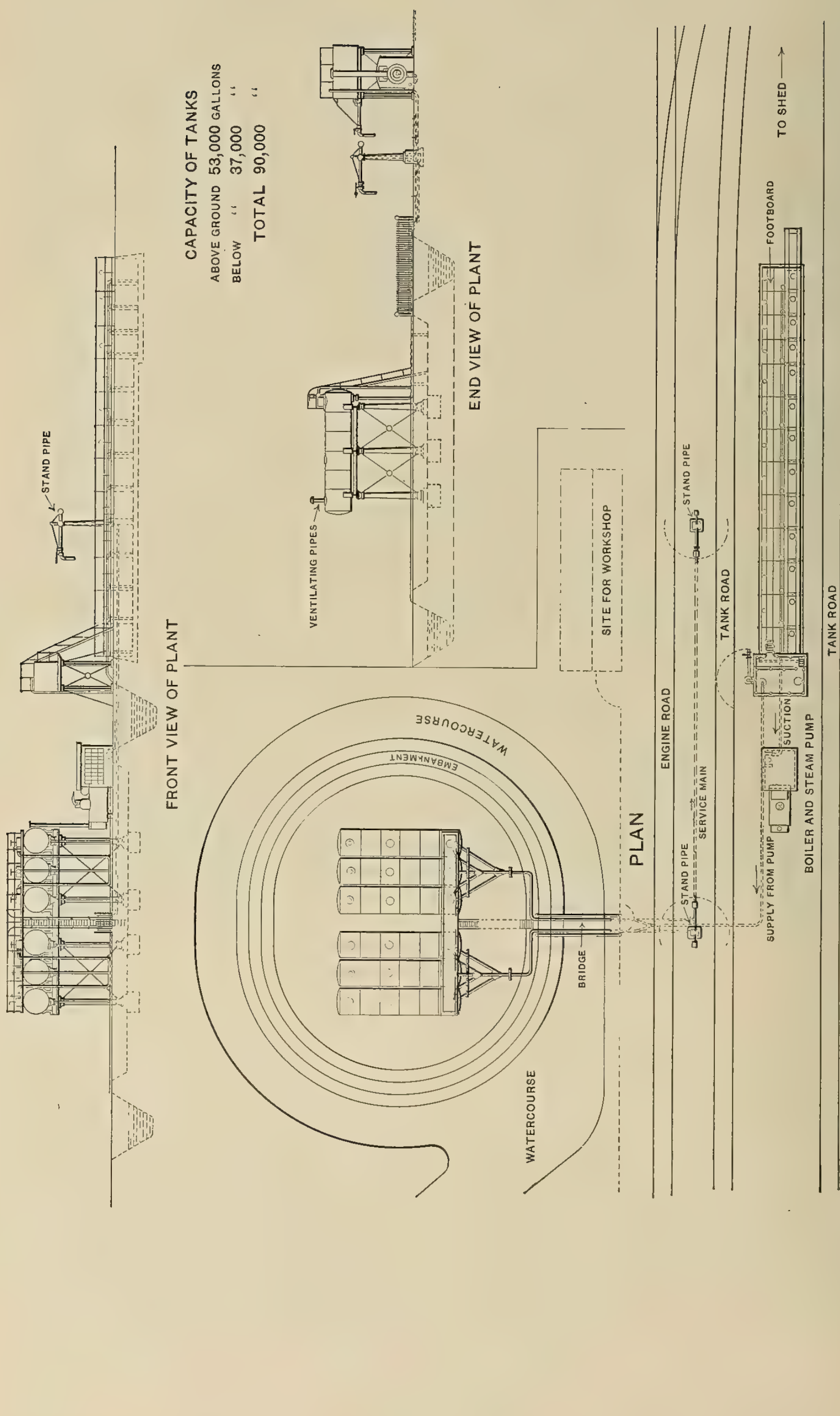
In Austria elaborate experiments have been made on the State railways with oil fuel fired on the Holden system, with the result that the whole of the locomotives working on the Arlberg tunnel service have been equipped with the apparatus. The illustration on the opposite page shows a train about to be worked over this section with an oil-burning engine.

The Arlberg tunnel is 6½ miles long, and great difficulty was experienced with its ventilation on account of its rise at the eastern end, the prevailing easterly winds preventing smoke escaping and causing serious inconvenience to the passengers and railway officials. So severely, indeed, were the latter affected that many cases of illness occurred. Coke was tried, but although an improvement was noticed in the smoke, still the fumes were most objectionable and the administration decided to use oil. In view of the late report by experts on the ventilation of the London underground railways a few notes from the data procured from the working of the oil-fired engines of the Arlberg tunnel may be of interest. The chemical laboratory of the University of Innsbruck has made a thorough chemical analysis of the following:—The air in the tunnel; the different fuels employed on the locomotives; and the fumes arising from the use of these fuels.



AN OIL-BURNING TRACTION ENGINE BELONGING TO THE RODESIA TRANSPORT COMPANY OF SOUTH AFRICA.

Atmospheric air contains from 0.025 to 0.035 parts of carbonic acid, and if this amount is deducted from that found in the tunnel after the different systems of firing have been used, the remainder will give the quantity of carbonic acid which can be directly attributed to the combustion of each particular fuel. With coke this amount is 0.195 parts; with "blue" oil, or heavy petroleum, it is 0.08 parts; and with tar oil it is 0.10 parts.



THE GREAT EASTERN RAILWAY COMPANY'S LIQUID FUEL STORAGE PLANT AT STRATFORD, LONDON.

The analysis of the different fuels gave the following results:—

"Blue oil" from Floridsdorf, S. G. 0.911, contains 86.63 per cent. carbon, 12.85 per cent. hydrogen.

"Tar oil" from Angern, S. G. 1.070, contains 90.50 per cent. carbon, 6.35 per cent. hydrogen.

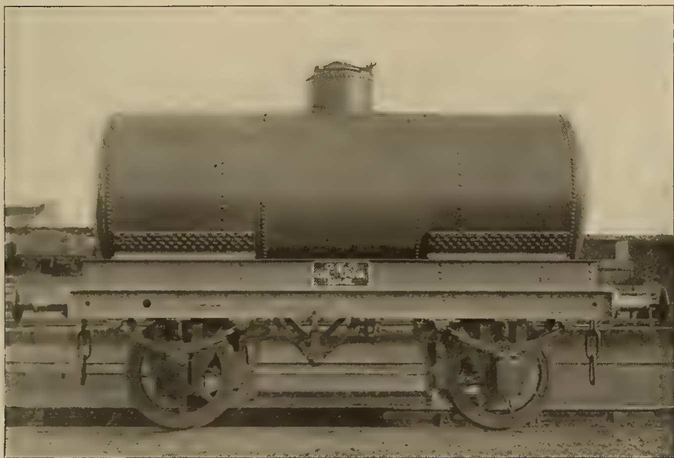
Gas oil from Oderberg, S. G. 0.919, contains 86.16 per cent. carbon, 11.79 per cent. hydrogen.

Residue from Ostram, S. G. 0.941, contains 86.65 per cent. carbon, 11.67 per cent. hydrogen.

During 24 hours the amount of oxygen absorbed from the atmosphere of the tunnel for combustion is:—

2807	cubic metres, when using	coal.
666	" " "	coke.
1065	" " "	"blue" oil.
1068	" " "	tar oil.
1433	" " "	gas oil.

As regards the economy of the oil fuel, it has been ascertained by careful trials of all the fuels that at the present prices of the district the use of the "blue" oil and gas oil is cheaper than coke. Another striking application of oil fuel to locomotive purposes is that of the Rhodesia Transport Company, who have recently adopted it for all their road locomotives working in South Africa. A typical example of this company's engines is the 10 H. P. (nominal) locomotive built by Messrs. John Fowler & Co., of Leeds, and shown on page 381. It is a two-cylinder com-



A LIQUID FUEL TANK WAGGON FOR CARRYING OIL TO THE GREAT EASTERN RAILWAY COMPANY'S PLANT AT STRATFORD.

The remaining percentage of oxygen in the atmosphere is reduced to

17.43	per cent. when using	coal.
18.75	" "	coke.
10.04	" "	blue" oil.
19.48	" "	tar oil.
19.56	" "	gas oil.

As atmospheric air contains 20.09 per cent of oxygen under normal conditions, the influence on the tunnel air of the kind of fuel used is obvious.

The following are the results of the analysis of the fumes or gases from the locomotives:—

pound, working with steam at a pressure of 180 pounds per square inch, with the driving wheels mounted on the maker's well-known patent spring system. It has one oil burner, and the tank holds about 60 gallons of the fuel.

Numerous other examples of oil-burning locomotives could be cited, but enough has been said to show that the employment of oil fuel is rapidly increasing. In conclusion, the writer would remark that, in his opinion, the introduction of the Holden system of

	When burning				
	Coal. Per Cent.	Coke. Per Cent.	Blue Oil. Per Cent.	Tar Oil. Per Cent.	Gas Oil. Per Cent.
Carbonic acid (dioxide)	15.15	3.73	8.53	8.80	10.10
Oxygen	2.45	16.53	9.74	9.76	8.11
Carburetted hydrogen	1.61	——	1.27	2.50	1.36
Carbon monoxide	0.17	0.03	0.14	0.11	0.10

burning oil has done more for this increase than any other, for it has removed the greatest objection that could be raised against liquid fuel, viz., the necessary alteration for the conversion of an ordinary coal-burning furnace to an oil-fired one. The advantages of oil fuel on a locomotive soon become apparent to those accustomed to the foot plate, for no matter how long the run, —and in these days the tendency is to make long runs without stopping,—there is a fire which, if properly adjusted, is always clean, always bright, always at its best; and after careful observation during a long experience of railway engines in various countries of the world the writer ventures to say that there are no locomotives operated more easily by the men than those which are fired with oil fuel.

THE BUILDING OF A SHIP.

By Lewis Nixon.

THE most important operation in ship building is to get some one to order the ship. The first step toward the construction of a new ship is its "scheme." This is a general and comprehensive outline of the qualities and characteristics desired, which, of course, are determined by the work which the vessel is intended to perform. If designed for passenger traffic mainly, the requirements will be speed, safety and comfort of accommodation; in such a case the "scheme" would contemplate a long sharp ship, with fine lines and elaborate fittings, and provided with high-powered machinery. If for freighting mainly, the "scheme" would involve a maximum of stowage and carrying capacity, with engines of moderate power, sufficient to drive the vessel at a comparatively low rate of speed with all possible economy of coal and other operating costs.

Having thus schemed the ship in view of her intended uses, the next step is the plan. This involves general drawings of the hull and machinery, with specifications sufficient to determine the quality of material and mode of construction. Upon the bases of the scheme and plan a contract is made between the owner and the builder. Naturally the character of the contract and the effect of its stipulations vary according to the notions or predilections of the buyer; but experience has demonstrated that the most effective forms of contract are those which define the desired objects in the clearest and most concise general terms and leave the multiplicity of constructive details to be settled according to the common-sense rules of business as the work progresses. That is to say, the private ship owner states the features he desires in his vessel, and awards the contract, not always to the lowest bidder, but to one in whom he has confidence, and with whose price he is satisfied, and leaves the detail to the builder. Governments get out elaborate plans and specifications and generally give out the contract to the lowest bidder.

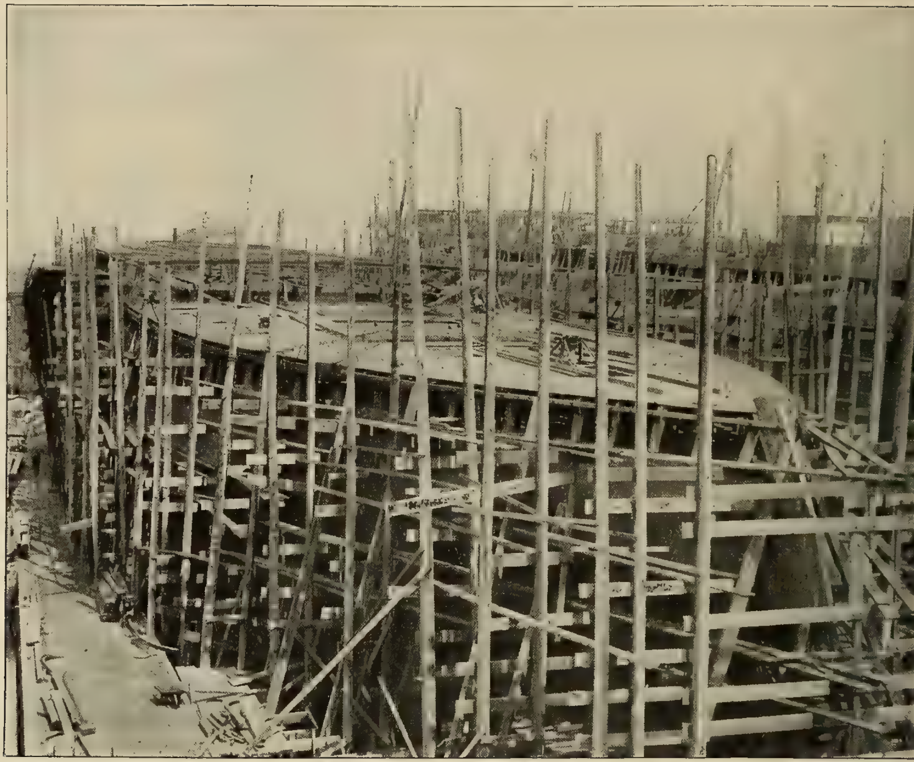
But as the form or method of contracting does not materially affect the process of construction in the mechanical sense, it is not pertinent to discuss it here, except to say that experience has not demonstrated the merit of superior economy in the government system as compared with that commonly pursued in work for private account.

Having settled upon what is wanted, the ship-builder proceeds to prepare the drawings and specifications of a vessel to fulfill the stipulated requirements. The plans prepared are:—

1. The lines, which are the projections on three planes of sections through the vessel, and which show the dimensions and shape of its outer surface before the plating is put on.

2. The sections, consisting of a plan of the midship section, and any other transverse sections of the vessel that are necessary to show the method of putting together, and the sizes of the various parts.

3. The structural plans, showing a longitudinal vertical section through the ship with the positions of decks,



A MAN OF WAR IN EARLY STAGES.

etc., and plans of the various decks, holds and platforms.

4. Joiner plans, showing the joiner work in the various compartments.

Preliminaries having been thus settled, the plans and specifications approved, and the contract put in force, the first steps toward actual construction is that of laying down the lines of the ship in the mould loft. The mould loft is a large floor, affording room for expansion of the lines and body plans of the ship to natural size. The "lines" are sections of the hull, cut longitudinally through horizontal planes for what are termed the "water lines;" through vertical planes for what are termed the "buttock" lines; and through diagonal planes, on a pitch of forty-five degrees from the middle line vertical plane of the ship, for what are termed the "diagonals;" and all these lines must coincide in what is termed fairness before the model is considered perfect.

The body plan is a projection of the principal frames or cross sections of the ship in one plane, of which the midship plane or "dead flat" is the basis, and all the other frames recede from it in regular order to the stem forward and to the sternpost aft. There again the points of intersection of the "lines" and the "frames" must be coincident, and that fact must be determined by the nicest measurements.

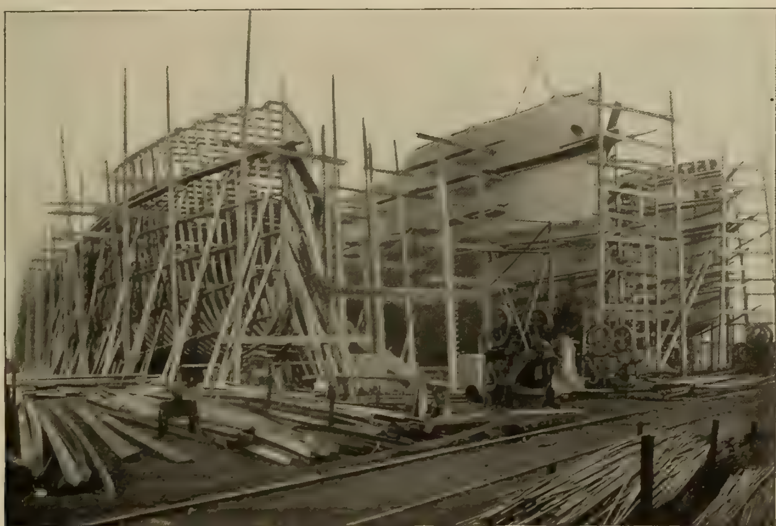
Instances have occurred where, through lack of accuracy in these adjustments, ships were built with unequal sides. One of them was the old American twenty-four-gun corvette *John Adams*, built in New England towards the end of the last century. She was well built and staunch so far as workmanship and material were concerned, but in consequence of the slovenly manner in which her lines were laid down and checked off, she had about six inches more beam on one side of the

middle line of the keel than on the other, which made her so lop-sided that her ballast had to be unequally stowed in order to trim her on even keel, and she would sail much faster and hold way much closer to the wind on one tack than on the other. However, such errors are practically impossible now in consequence of improved methods and the multiplication of devices for discovering and checking error.

Simultaneously with this work in the mould loft, the force in the drafting room is busy drawing and tracing similar lines and body plans on paper to a scale of one-quarter or one-half inch to the foot of actual dimensions obtained from the loft, and these are embodied in a wooden model usually representing a "half-breadth," or one side of the proposed ship in miniature, and on the surface of this model the sizes of the plates are "laid off" by lines showing the edges and butts of the plates and also the outlines of the deck or stringer plates. When this model is completed, each plate is marked with a letter for the strake to which it belongs, as, for example, strake *A*, strake *D*, etc., and a number for the plate itself, the numbers running from forward aft. This model now forms the basis of the expansion plans of the framing and plating, from which the dimensions of each frame and each plate are determined, and this calculation, in turn, forms the basis of what are called the "schedules of material," which are dimensional descriptive catalogues, embracing each individual piece of iron or steel entering into the construction of the vessel.

These schedules are now forwarded to the iron or steel makers, who proceed to manufacture the plates and shapes in accordance with their requirements. Plates are usually ordered about an inch longer than the finished size, and sometimes, though not always, half an inch wider.

The tests demanded for ship plates and shapes for the merchant service are not so elaborate as those required by navy departments. Lloyd's Register requires for merchant vessels that the quality of the steel shall be as follows :—



ON THE STOCKS IN THE YARD OF PALMER S SHIPBUILDING AND IRON CO., LTD., JARROW ON TYNE, ENGLAND.

Strips cut lengthwise or crosswise of the plates, also angle and bulb steel shall have an ultimate tensile strength of not less than twenty-eight tons, nor more than thirty-two tons, per square

RIVETING UP A SHIP'S FRAMES BY TWEDDELL HYDRAULIC MACHINERY.

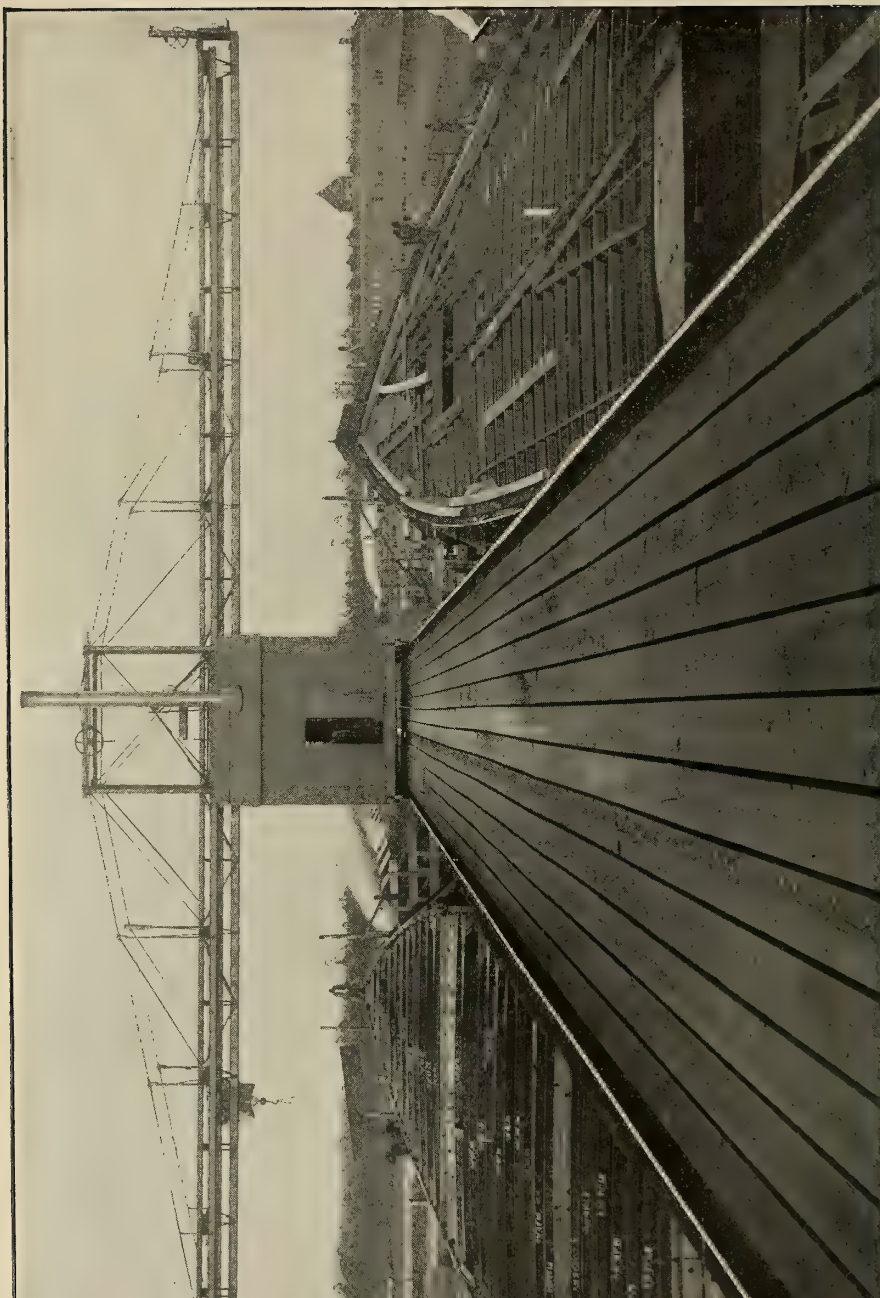
inch of cross section, with an elongation equal to at least 16 per cent. on a length of eight inches before fracture. Steel angles for frames and bulb steel for beams may have a maximum tensile strength of thirty-three tons per square inch of section, providing they be capable of standing the bending tests and of being efficiently welded. Strips cut from the plate, angle or bulb steel, heated to a cherry red, and cooled in water of 82 degrees Fahr., must stand bending double around a curve, of which the diameter is not more than three times the thickness of the plates tested.

The steel used in the men-of-war building for the United States Navy is subjected to exhaustive physical and chemical tests, the general requirement being that it must have a tensile strength of 60,000 pounds per square inch and an elongation of 25 per cent. in eight inches, and that the proportions of sulphur and phosphorus and other harmful ingredients shall not exceed certain amounts. The steel must be open-hearth, but there is no requirement that it shall be by the basic or acid process. However, it is now the general opinion that acid open hearth steel is the more reliable.

In ordering materials, the schedules are sometimes submitted to a number of concerns for competitive bids, and sometimes orders are given outright without competition, according to the best judgment of the builders. Of course, the object is to secure delivery as nearly as possible in the order of its incorporation in the ship and, therefore, the first plates ordered are those which are fashioned to form the keel.

A HYDRAULIC SHIP PLATE PUNCHING MACHINE, BUILT BY MESSRS. HUGH SMITH & CO., GLASGOW, SCOTLAND.

The next step is to prepare the blocks on which the vessel is to be built and from which she is to be launched. The blocks consist of a number of short beams or balks usually of yellow pine,



A TRAVELING CRANE IN THE NEWPORT NEWS, VA., SHIPBUILDING AND DRY DOCK COMPANY'S YARD.

raised to a sufficient height from the ground to enable the workman to pass freely under the keel at all points, and they are generally spaced from four to six feet apart along the whole length of the ship. Care must be taken to provide a foundation for the blocks, generally by driving piles of sufficient solidity to prevent the least settling, as the weight of the ship upon them increases with the progress of construction. The blocks are laid with an upward slope from the water to give the hull the necessary inclination for launching. As a rule, this slope is about five-eighths of an inch to the foot, which, in the case of a vessel like, for example, the American line steamer *St. Louis*, elevates the bow about twenty-eight feet above the level of the stern.

Naturally, the line formed by the top surfaces of the blocks must be an exact mould of the keel. To perfect this adjustment a mould is made from the "sheer-plane" of the ship (the sheer-plane is the longitudinal section cut on the middle line fore and aft), showing the exact sweep of the keel, and the blocks are faired up to this mould.

All preliminaries having now been completed, foundations are made on each side of the blocks to sustain the "ground ways" for launching, and, the necessary material being on hand, the keel is laid.

There are several kinds of keels. If the design calls for a centre keel it may be either a "bar-keel," which is a solid bar of forged iron in suitable length, scarfed together from stem to stern, or a "box-keel," which is built up of plates, riveted together and forming a hollow trough, so to speak. The present practice, however, particularly in naval vessels and, to a growing extent, in merchant ships also, is to make the centre keel flat, or coincident with the bottom of the ship, and to attach a short projecting keel to each bilge of the vessel, the principal office of which is to prevent violent rolling. In fact, the centre keel is an inheritance from the days of sailing power, when its chief office was to aid in holding the ship up to the wind when running close-hauled on a tack; but in vessels propelled entirely by steam, this need no longer exists and the consequence is the gradual disappearance of the bar-keel in the more modern construction.

The dimensions of the plates for the keel depend on the size of the ship. In the case of a merchant ship they are settled almost entirely by the rules of ship building, which, to a large extent, in the United States, are according to the American Shipmasters' Association and in England according to Lloyd's register. These rules fix the size of the scantling, and must be followed, as they are made a basis of insurance by the underwriters. That is to say, the endorsement of such associations is the hall mark of marine construction. The sizes of the scantling are fixed by what is known as a scantling number, which is dependent upon the length, breadth, depth, girth, or longitudinal section of the ship.

I have often seen young college graduates come into a drawing room, expecting to be put at once upon calculating stresses and strains, only to find themselves put to picking the sizes out of a book of rules. However, they soon find that to use such a book to the advantage of their employer requires a great deal more of care and experience than to work out a formula. This is not so in the case of a man-of-war where all this is generally calculated, the man-of-war usually being stronger than a merchant ship on account of greater subdivisions, and as government vessels do not seek insurance, they are not bound by underwriters' rules.

As soon as the keel is laid, the frames are bent. In order to have the frame exactly fair, it is, in some ship-yards, taken from the bending slab to what is known as a press, which is worked by hydraulic power or hand, where it is pressed to the exact shape of the wooden mould which is taken from the body plan. In order to make this doubly sure, it is taken to the blackboard from which the wooden mould was formed and laid directly on the board, and if there has been any change in shape by virtue of its being heated and cooled, it

is pressed again or hammered until it corresponds exactly to the shape of the line of the ship. Each frame has been bent for a particular position, this place being fixed on the keel.

In placing the frames at various points, we begin, as a rule, with the midship frame. This is raised by tackles, worked from a pair of derricks, one on each side. The regulation of the first frame is very important, and, when raised, this frame is shored and regulated in proper plane and in exact position. Sometimes a beam is raised with it. Each subsequent frame forward and aft of the midship is raised in its turn and regulated both by its own bearing to the keel and by that of its next neighbour.

There are two general systems of bottom framing, called the transverse, and the longitudinal, or bracket, system. In the former the floor plates are continuous from the vertical keel on each side to the bilge and the keelsons are worked in short sections, called intercostals ; but in the longitudinal system the keelsons extend continuously, parallel to the vertical keel for a considerable distance amidships, and the floor plates are worked between them in short sections, called brackets.

This system is now almost universal in double bottomed ships, whether designed for naval or commercial purposes, and the longitudinals usually extend the whole length of the boiler and the machinery spaces, the ends of the ship forward and aft of these limits usually being carried out on the transverse system. The effect of longitudinal construction is to impart great rigidity to the hull, and it is considered imperative in the best practice in all cases where ships are to be provided with heavy engines, and to sustain the strain due to the exertion of the great power required for high speed. Single bottomed

HYDRAULICALLY RIVETING UP THE KEEL OF AN ATLANTIC LINER.

A DRY DOCK VIEW OF THE AMERICAN LINE STEAMER "NEW YORK," AT NEWPORT NEWS, VA.

ships, built on the transverse system, are now in almost all cases stiffened by running heavy Z bars or angle bulbs fore and aft, worked on top of the floor or inside of the frames.

We now come to the plating of the ship. The floor plates are fastened to the longitudinals by angle-clips; the outside plating by angles on its bottom, and the inner bottom plating by angles on its top. Ships are plated in various ways, but the most common is what is called the raised and sunken strakes.

The first strakes to be put in place are the inner ones. The edges are marked on the frame or nicked and these are generally faired in. In taking off the strakes, a template, or mould, is made up of thin boards, somewhat larger in outside dimensions than the plate, and cross battens are fitted on the templates at the frames. This template is put up against the frames and held in place by little bent irons and upon it are marked the edges of the butts and the position of the rivets. Then the template is taken down from the ship and laid on the plates, showing, thus, the exact size of the plate and the position of all the rivet holes in it.

NINETY-TON SHEARS IN THE YARD OF THE NEWPORT NEWS SHIPBUILDING AND DRY DOCK CO.

The edges of the plate are then sheared approximately to shape and the butts are planed to the lines obtained from the template, after which the position of the rivets in the edges and butts is laid off; then the holes are punched and countersunk and the plate is put through the bending rolls to give it the shape of the side of the ship. If there is much shape, iron moulds are taken out for each frame, that is, a piece of soft iron at each frame, and this gives the shape to be followed in bending the plate. In some ships some parts have to be flanged out and bossed. The plate must be taken to the furnace and shaped according to the wooden mould or pattern. When the plate has been sheared, planed, punched and countersunk, as described, it is temporarily put in place and bolted up.

When it comes to working on the outside strake, the same kind of template is used, but from this same template must be obtained the position of all holes in the edges, as they must fit in the holes which have been laid off in the inside plate. The plates of the outside strakes are punched from the inside, and the holes for the edge rivet for the inside strake must be punched from the outside, while the holes for the rivets securing to the frame and butt fastenings must be punched from the inside. In order to fill up the space which exists between the outer strake and the frame a "liner" is put in. Little templates are made for them and they are fitted in place after the frames are up. A machine has been patented in England which puts an offset in the edges of the outside strake and so does away with liners. After the preparation is completed, the rivets are driven in place.

While the plating is under way, the work in the inner ship is advancing, and the riveting of the plates and angle pieces is going on. The temporary bolting, spoken of, is for the riveters. The plates are hung by two or three bolts only. This is done by sub-contract usually. In the meantime we are getting in the beams or rafters of the deck. Work is advancing on the inside of the ship all this time, and plating for the deck is going on.

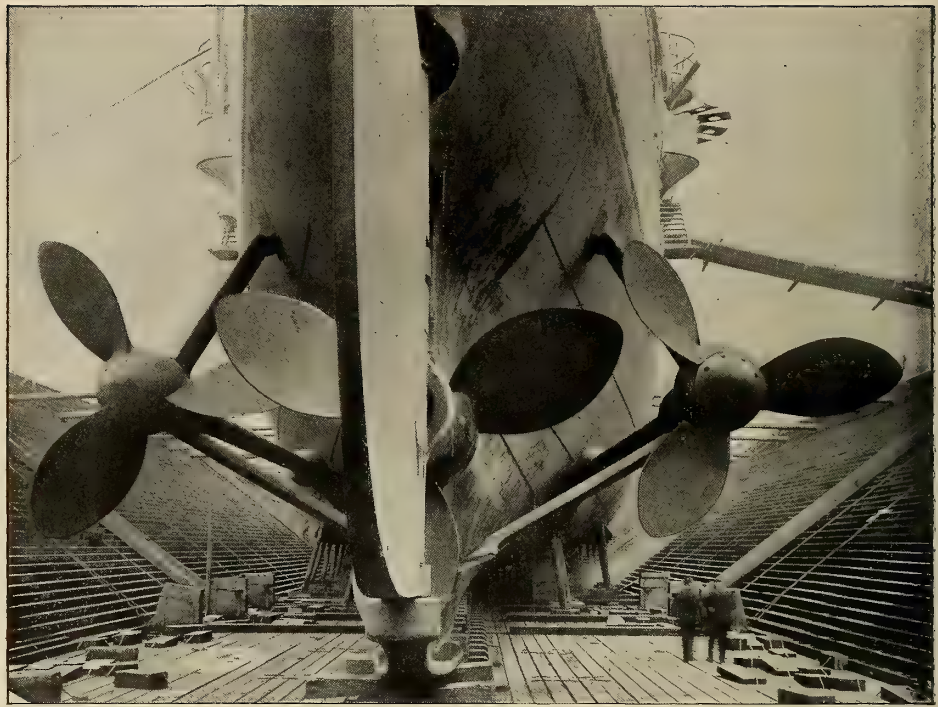
The part of the decking next to the side is called the stringer plate. The bulkheads forming subdivisions of the ship are turned out practically the same as the side plating, and templates are made for them in the same way. They are stiffened with angles or other stiffeners, so that they can stand the strain of bodies of water which may get in the vessel, and keep them from getting into another part of the ship.

Size of the rivets is specified, or divided generally into two classes,—water tight and non-water tight. The rivets in the edges and butts have all water-tight spacing so that they will hold a calked joint; but in the frames, where their office is simply to hold on, their spacing is wider and is regulated by the strain to be withstood.

After all the rivets are driven, a man goes around and tests them with a hammer. If any are found loose, they are cut out and new ones driven. Every rivet is thus inspected, and, when approved, it is painted. The rivets are heated red in a rivet furnace, and passed by a boy to the place where they are to be used. The riveting gang proper consists of two riveters and a holder-on, that is, the rivet is put in the hole, held in its place at the back, and driven by riveters, of whom generally one is right and the other left-handed. In some parts of the ship only one man can drive.

When the riveting is advanced to some extent, the edges and butts are calked, which is simply knocking down the material so tight that the water will not pass through it. This is done either by hand or by an ingenious little machine of recent invention, called a pneumatic calker. Government work is generally tested with water under pressure. In merchant work, except for carrying oil in bulk, this is not generally done, but it is simply inspected by the company's man or the insurance surveyors, and after this inspection it can be painted.

As soon as the ship has been framed and plated up and the main structure



THE UNITED STATES TRIPLE SCREW CRUISER "COLUMBIA" IN THE DRY DOCK.

completed, we come to the question of laying the decks and other wood work generally. The decks are made from three to four inches thick, and are bolted with deck bolts, the head of the bolt being sunk below the surface of the deck, and the cavity filled up with a plug of wood above, so as to make it appear like a solid piece of wood.

When the frame of the ship has been completed to the ends, the stem and stern posts are erected in place. Formerly these were of forged iron, but now they are usually made of cast steel in large vessels. All large steel-plated men-of-war have stem and stern posts of cast steel. They are put up in place and the keel plates are worked around and riveted to them. The stern post in a single-screw ship is bored for a screw tube, and, generally, the after section of the screw shaft and propeller are put in place before launching.

In the foregoing brief survey of the process of ship building, details have necessarily been avoided, because an attempt at particular description of all the divisions and sub-divisions of the industry would here be inadmissible. In many directions the genius of the age has expressed itself in labour-saving machines of various kinds and in improved handling appliances. But notwithstanding all this, the fact remains that a very large proportion of the skilled work pertaining to the construction of a ship's hull is still done by hand, and, in the nature of things, must continue to do so. Certain parts may be built up separately by the hydraulic riveter before being put in place ; but the use of this machine is necessarily limited in its scope, and the greater part of the riveting, drilling in place, chipping and much of the calking, must be done by hand now and in the future as heretofore.

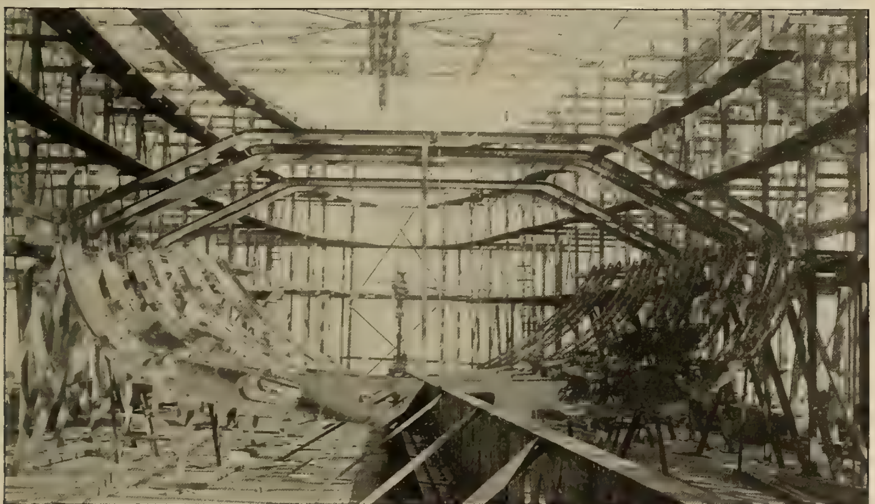
The vessel is built, as before stated, on a foundation of keel blocks extending her entire length. She is further supported by numerous heavy shores or props. Before launching we must lift

her from the keel blocks and the shores must be removed, so that an entirely new system of supporting her must be provided.

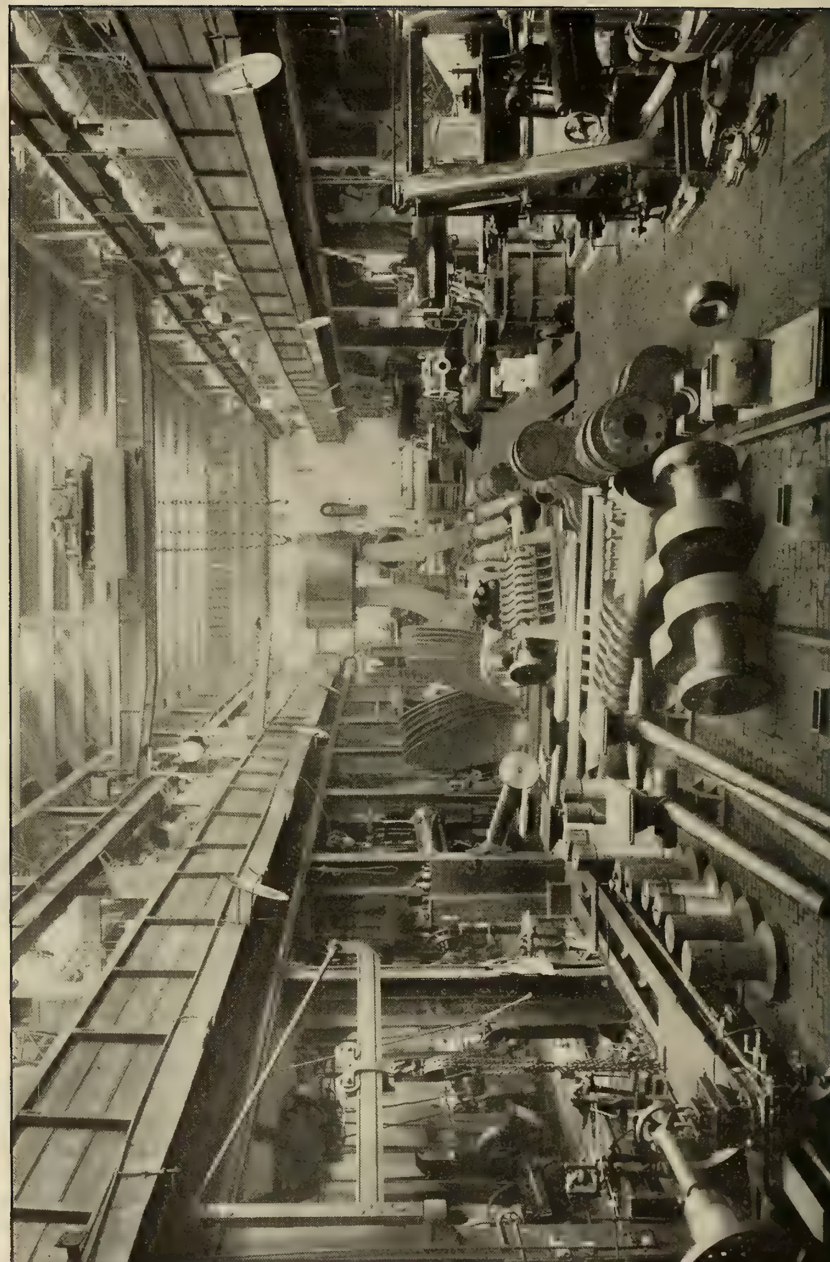
The launching ways consist of the ground ways and the bilge, or sliding ways. The ground ways are fixed tracks, laid on piling and blocks, one on each side of the vessel, extending well down into the water. On these the sliding ways are laid, tallow and oil being put between them, so that the upper ways can slide easily along the ground ways into the water. From the sliding ways to the bottom of the vessel, packing of wood is fitted, carrying the ground ways up to the bottom. When wedges are driven in between the sliding ways and the packing, it is easily understood that the ship will be lifted up and supported on the two ways which are about one-third of the width of the vessel apart. Now if the keel blocks and shores are removed, we have the vessel supported entirely by the launching ways. The upper end of the sliding ways is carried out at a thickness of about four inches and this is bolted through to the ground ways. This is what holds the vessel and as soon as it is sawed off, she slides into the water.

Launching is always the most delicate part of the ship-builder's work. It involves the greatest responsibility, concentrated in the shortest time and with little or no opportunity to avert the consequences or retrieve the results of any serious errors, and this responsibility is augmented in a highly progressive ratio by the size and cost of the vessel to be "put overboard," as launching is usually termed in the parlance of the ship-yard.

Many things may happen to disturb the symmetry of a launch. If the weather be extremely cold, the tallow between the ways may not act properly and it may be necessary to force the vessel off by hydraulic jacks. There have been instances where a vessel, launched with a number of people on board, capsized because of neglect to provide proper ballast, or recklessly imperfect calculations as to her initial stability, causing a great loss of life. In view of such possibilities, the crowning moments of a ship-builder's career are those, when by reason of the perfect adjustment of every mechanical appliance, accurate calculation of every mathematical factor and the perfect execution of every manual detail, a large ship glides noiselessly down the



THE FRAME WORK OF THE U. S. CRUISER "OLYMPIA" IN THE YARD OF THE UNION IRON WORKS, SAN FRANCISCO, CAL.



THE FITTING SHOP OF THE WALLSEND SLIPWAY AND ENGINEERING CO., LTD., NEWCASTLE-ON-TYNE, ENGLAND.

slope on her ways, like a thing of life, and takes to her destined element on a perfectly even keel with a graceful dip of her bow to an admiring audience, and then floats with the tide as if serene in the majesty of a graceful *debut.*

No one who has not felt the responsibility of such work can even faintly appreciate the triumph of such a result. When the vessel is launched, she is at once taken to the shears, and the boilers and engines are hoisted on board and the whole vessel carried on to completion.

We now turn to another branch of our theme, to which recent developments and modern genius have lent an interest equal to that which appertains to the building of the ship. This is the design and construction of her motive machinery. The reason for this interest seems not too far to seek when one contemplates the enormous and intricate, yet, to the practised hand, simple and obedient monsters of steel, iron and brass, which, as if instinct with animate sense, throb to the mighty breath of steam in the bowels of the great ship, regardless of the elements and defiant of storms, converting to the most commonplace uses of art the most colossal forces of nature.

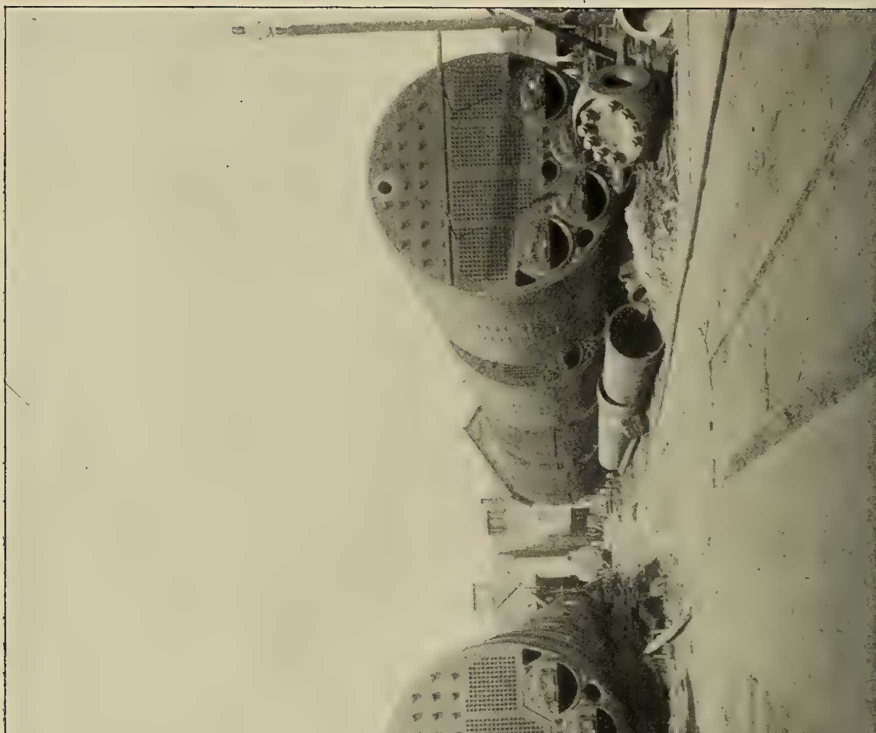
As stated at the outset, an essential element in the "scheme" of a new steamship is the general outline of her boilers and machinery. The size and character of the ship having been determined with reference to her proposed uses, the next step is to allot certain spaces and weights to engine power sufficient to give her the contemplated speed. We will not stop here to discuss the important difference of conditions which prevail in this respect, between vessels designed for commerce and those calculated for war, except to remark that such a difference exists and is now a recognised factor in the science of marine engineering; and to explain generally that in the construction of engines for war-ships, economy of weight and space in proportion to power is the chief *consideratum,* while in the case of merchant vessels, whether for freight or passenger traffic, economy of coal consumption is mainly sought.

As soon as the plans of the ship are sufficiently advanced in the construction or hull department, drawings of the frames, floors, etc., throughout the space allotted to machinery are taken off and furnished to the engine department as a basis for detailed design of the boilers, machinery and coal bunkers. With these data as a basis, the designing of the motive machinery begins. The approximate horse-power required to produce the speed contemplated in the scheme of the ship having been previously decided, the problem now is to provide that power on the most economical basis within the limitation of space and weight that has been determined on. This involves a great number of considerations. The principal ones are:—

1.—Dimensions and characteristics of boilers, such as length, diameter, number of square feet of grate surface and of heating surface, working steam pressure, dimensions of steam pipes and their valve connections, location and capacity of coal bunkers, arrangement of fire rooms; and if forced draught is to be used, provision for blowers.

2.—Dimensions and numbers of main steam cylinders, such as the piston diameter of each, length of stroke, or piston speed required to produce the required power, dimensions of working parts necessary to withstand the strain incident to the amount of power to be put through them, character of valve gear, and dimensions of valve openings, type of actuating and reversing gear, dimensions of crank and driving shafts, adjustment of bearings, and diameter, pitch and form of propeller screw, or screws, if a twin-screw ship.

3.—Arrangement and adjustment of all auxiliaries, such as air pumps, freeing pumps, steering gear, hoisting gear, etc., if a merchant ship, and numerous other mechanical appliances connected with the operation of the battery and gun protection, if a man-of-war; dynamos and other elements of electric lighting apparatus, evaporators and distillers to produce fresh water on board, and a



THE BOILERS OF THE UNITED STATES ARMOURED CRUISER "NEW YORK." BUILT BY THE WM. CRAMP & SONS SHIP AND ENGINE BUILDING CO., PHILADELPHI

thousand and one other details, each apparently minor in comparison to the importance of the main engines, but each indispensable to the perfect economy of the masterpiece,—the marine engine as a symmetrical whole.

When all these details have been elaborated, and the necessary drawings and calculations perfected, patterns for the castings, and the expansion plans for forgings are made, and orders are given for the material.

The principal castings are the bed plates, cylinders with their valve chests, frames, if the engine be vertical; shaft tubes and struts, or outboard shaft supports, if a twin-screw steamer; cylinder covers, pistons, pillow blocks, cylinder liners and many other castings of less size and note in iron or steel, and all working bearings in brass or white metal. The very highest qualities of iron or steel are required in these castings, the cylinders and their appurtenances being made invariably of the best charcoal iron in all approved practice.

The principal forgings are crank shafts, line shafts, and thrust shafts, piston rods, connecting rods, cross heads, rock shafts, link bars, valve connecting rods, eccentric straps, air-pump connecting levers if the air-pumps take their motion from the main cross heads,—supporting columns in vertical engines and stay rods in horizontal ones, with smaller forgings too numerous to mention.

In all well-ordered ship building the construction of the boilers begins with the laying of the keel. In no department of ship building are skill and experience of more vital importance than in the boiler shops; for the boilers are to the steamship what the heart is to the human body, and upon the proper discharge of their functions depends the whole efficiency of the structure. There is, doubtless, wider difference in quality of boiler work and in consequent performance between different establishments than in any other branch of the art. Some shops turn out boilers which begin with first-class performance on the preliminary trial trip and maintain that standing throughout their period of duration; others begin with leaky tubes, sprung tube sheets and bad joints, and continue an unsatisfactory career until they land in the scrap heap at a time when a good boiler would be at its best.

Slovenly work on a ship's hull may be remedied by thorough repair. Even imperfect construction or defective adjustment of the working parts of an engine may be corrected. But there is no salvation for a botched boiler, because one defect always breeds another. Steam at 160 pounds square inch pressure is an agent that will tolerate no trifling, and, hence, unless the boiler is perfect at the start in every detail, the cheapest disposition that can be made of it is to break it up and put in a new one that is perfect.

The boiler in most common use for sea-going ships is of the cylindrical, fire tube type, with inside furnaces, and is usually termed the Scotch boiler. Other types are used, such as the "through and through" or locomotive boiler, and the water coil or tubulous type, of which there are many kinds. The essential difference is that in the cylindrical and locomotive types the fire goes through the tubes, which are immersed in water, while in the coil type the water is forced through tubes surrounded by fire.

The great amount of water required in the Scotch boiler is rapidly bringing about a more extended use of the water tubular kind. The earlier water-tube boilers did not have enough water to act as a heat reservoir, but the necessity for more water to insure uniformity of pressure is being recognised and it is very probable that the coming boiler will be a tubular boiler with enough water in some large tube or tank to act as a water and steam reserve.

Recent improvements in material, and enlargement of the capacity of rolling mills have enabled builders to augment the size of cylindrical boilers to proportions not dreamed of a few years ago. This is not only an essential condition in the building of large and high-powered ships, but it also conduces largely to economy of fuel and fire-room work, as the co-efficient

LAUNCH OF H. H. S. "POWERFUL," BUILT BY THE NAVAL CONSTRUCTION AND ARMAMENTS CO., BARROW-IN-FURNESS, ENGLAND. TWIN SCREWS. INDICATED HORSE-POWER, 25,000. DISPLACEMENT, 14,000 TONS. SPEED, 22½ KNOTS. BELLEVILLE BOILERS.

of performance increases in a rapidly progressive ratio with the enlargement of the boiler.

In present practice, more than one-half the work on a marine boiler is done by machinery. All the planing, bending, flanging and drilling of the main plates is done by machinery, and the whole of the shell is riveted up by the hydraulic riveter. Hand work is now mainly confined to the fitting and riveting of the furnaces, tube-sheets and boiler heads, fastening the tubes and stay bolts, and calking the seams.

As soon as the first consignment of shell plates is received in the yard, they are planed to exact size and the plates forming the first ring, or section, of the boiler are bent to exact shape. These are then secured in place on a circular drill table and the second ring is bent and fitted to them. The rivet holes are then bored in place, through and through, thus insuring exact coincidence. The third ring, if a double ended boiler, is then treated in the same manner, when the plates are fastened in place by a sufficient number of bolts to hold them, and the structure is picked up by cranes and transferred to the hydraulic riveter.

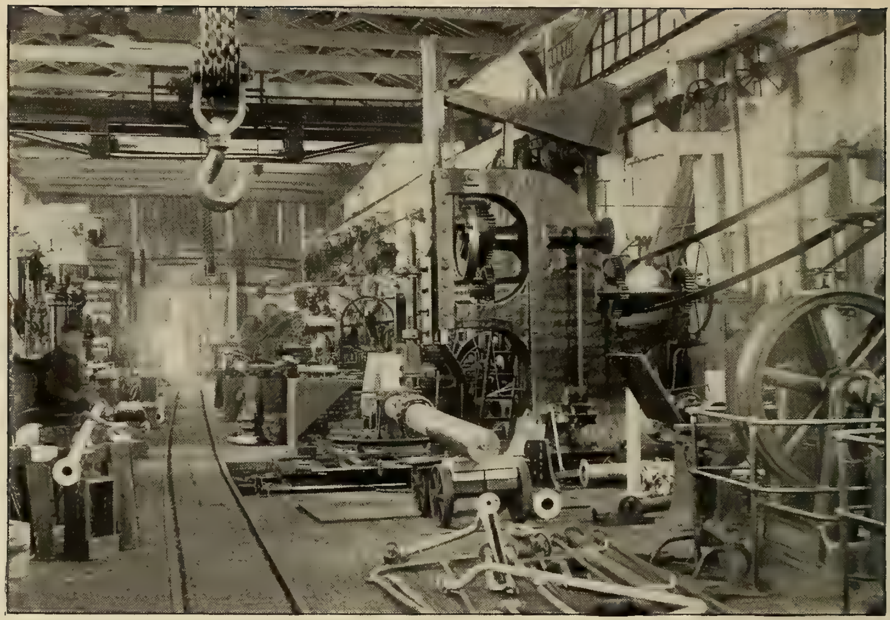
This is a machine with two heavy vertical jaws, having a sufficient opening between them to admit the shell of the boiler freely. One jaw carries a hydraulic cylinder and plunger, while the other holds a fixed die on the same axis as the plunger. The shell is swung between these two jaws, and hot rivets are handed up on the inside, each rivet hole being brought, in its turn, in line between the plunger and the die, and the rivet is driven home by a single impress. The force exerted is many tons to the square inch, varying according to the size and pitch of rivets employed.

The flanging press also is a hydraulic machine. It consists of a vertical pressure cylinder actuating a plunger which is provided with cast-iron dies of whatever shape and size may be needed to produce the desired flange. The plate is heated to a bright red and placed in position on the die, exact adjustment having been previously made by measurement, and the power is applied. Some flanges are produced by a single operation, while others require several impressions, according to the size of the plate and the depth of the flange.

The boiler having been completed, all joints calked, tubes secured, stay-bolts set up, manhole covers fastened and pipe connections seated, it is tested under a pressure much greater than that at which it is designed to work, and is then taken to the boiler wharf in readiness to be put in place on board ship.

In the meantime, the engine has been undergoing similar progress in the machine shops, and as fast as its parts are completed they have been assembled on what is termed the erecting floor, or platform, in the same positions they would occupy on board. In other words, the engine is completely set up in the shop and all its parts are thoroughly adjusted, except the steam pipe connections. In this operation, all the guides, piston rod, crosshead and connecting rod bearings are carefully centred and trued up, the crank shaft bearings are tested and perfected by means of cast-iron mandrils which are facsimiles or templates of the shafts, and finally the crank shafts themselves are put in place, connected and turned over. This is one of the most delicate processes known to mechanical art, and upon the fidelity with which it is accomplished depends much of the success of the machine. No triumph can excel that of the marine engine builder, who sees the creation of his skill start off on preliminary trial without hitch or jar and, from the first, realise the full performance designed or guaranteed.

The engines are now taken apart in the shop,—or "broken up" as the saying is,—and are transferred to their destined places in the ship, piece by piece. The boilers are put on board, secured in their saddles, the pipes are connected, and the vessel is ready for what is called the dock trial. This is a trial of the engines with the ship securely moored to the wharf, and is continued for twenty-four hours or sometimes as



SHIPYARD FITTING SHOP OF PALMERS SHIPBUILDING AND IRON COMPANY, LTD., AT JARROW, ENGLAND.

long as forty-eight hours, during which time the operation of every part of the machinery is carefully inspected, and small defects, if any, are made good. The delivery of steam, action of condensers, function of the pumps and valves, performance of the boilers, operation of the bearings, efficiency of lubricating apparatus,—in short, every item in the sum total of the work of the machinery is closely observed and exhaustively noted.

After the dock trial nothing remains but the sea trial which, in the case of some ships, is often nothing more than a trip from the ship yard to the wharves of their owners, where they are approved, received and the balance of the contract price paid. This is the usual method with merchant steamships.

But governments are more exacting. They are not satisfied with one trial. When a naval vessel is finished and ready for trial, the department appoints a board of officers who inspect her from stem to stern, and from keelson to truck, to see if the other inspectors, who have watched the driving of almost every rivet during her construction, have done their duty. This order passed, the board takes possession of the ship and she goes out for a sea trial.

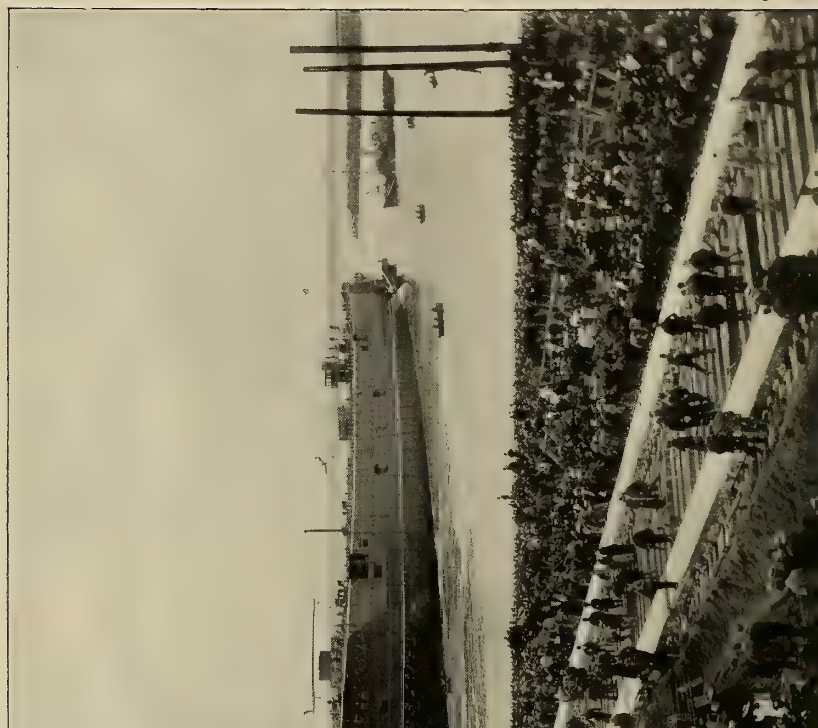
If the conditions of her contract require a guarantee of indicated horse-power, her engines are put at full speed for four hours, and indicator cards are taken of each end of each cylinder every fifteen minutes. When she returns to port the indicators are taken to a navy yard and tested to see if their springs have weakened any under the ordeal to which they have been subjected. The cards are then computed and the factor of decreased "weightage," which may be one one-hundred thousandth of the total resistance of the spring, is carefully differentiated in ratio through the sixteen cards. These are then calculated by the rule of a mean result of several means, and after some weeks the builder is officially informed that his engines have developed a certain number of units of indicated horse-power, plus certain one-hundredth parts of the same.

In other cases, and this is not the regular practice, the vessel is tried on a guarantee of speed in knots per hour. The contract stipulates that she shall be

tried at a certain draught and displacement, which are officially termed normal. Hence, after the quantity of coal and stores necessary for the trial trip are on board, the vessel must be brought down to her normal load line by extra weights.

In placing these on board, the naval inspectors require that the equivalent of each gun, with its carriage and accessories, shall be located on each gun sponson or other place of mount; the equivalent of the regular ammunition shall be stowed in the magazine; that of the ship's stores shall be disposed in the places between decks; and that of the remaining coal supply in the bunkers, so that the relation of trial weights to the buoyancy and stability of the vessel shall, as nearly as

THE TRIPLE SCREW U. S. CRUISER "COLUMBIA," BUILT BY THE WM. CRAMP & SONS SHIP AND ENGINE BUILDING CO., PHILADELPHIA.



H. M. S. "POWERFUL" AFTER LAUNCHING.

possible, conform to the conditions of actual service. The regulation limit of speed trial duration is now four hours, and the practice adopted by the United States Navy Department, for example, is to make two runs over a measured course of half the distance which the vessel is required to make as a whole, the professed object being to equalise as far as possible, the effect of tides, currents and winds which may prevail during the run.

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HOISTING A BOAT FROM A MAN-OF-WAR'S DECK.

So far as this method has been practised in the United States, little is to be said in its favour; at least anywhere on the Atlantic coast. The water is too shallow to admit of running close enough inshore to make use of land-marks or fixed ranges, and hence recourse must be had to buoys or vessels anchored as markers, both as to the ends of the course and to indicate its line. Of course, these are subject to variations which, in measuring the speed of a vessel going twenty knots an hour, or a knot in three minutes, might considerably affect the result.

However, the run is made under these conditions, and after a careful computation by the trial board, the builder is officially informed that his ship has developed a speed of a certain number of knots per hour, plus a certain number of one thousandths of a knot, which is important, as a thousandth of a knot is 6.08 feet, and a vessel going twenty knots an hour, requires eighteen hundredths of a second to traverse that distance. In view of the fact that the unequal drift of ships or buoys, moored as markers either of the ends of the course or of its line, might easily affect its actual length a quarter of a knot or more, this accuracy

of reporting the speed developed to thousandths of a knot would seem to be indispensable.

We shall now pass to the commercial side of ship-building, which is undoubtedly its most important side. Where you can find twenty men who can design and build an engine, you cannot find one who can tell you what it cost. It is difficult to give any figures on costs of ships. Battle ships, like the *Indiana*, of the United States Navy, cost for hull and machinery about three hundred dollars (£60) per ton of displacement. The cruiser *Baltimore* cost the same. A passenger steamer will cost from one hundred to two hundred dollars (£20 to £40) per ton of displacement, depending on the speed and finish.

The only sure way to estimate on the cost of ships is by comparison, so that an old-established yard, in which have been built all sizes and classes of ships, whose cost has been carefully kept, has an important advantage over a new yard. The adage, that "fools rush in where angels fear to tread," is forcibly illustrated often in bidding on vessels, where the amateur on such work, basing his figures upon some vessel whose price he knows or thinks he knows, is awarded a contract at a price far below veteran ship yards, and naturally finds that he cannot build the ship for the money. You can trust to luck in many things, but it is never safe to do so in estimating cost.

It may not be amiss, in concluding, to state that naval architecture is one of the greatest of professions, and one in which excellence is justified from the fact that defects in a ship, like murder, will out. An architect for a house may build his house too strong and so heavier than it need be, but Mother Earth is patient and bears the added weight without protest. But build your ship too strong, and you lose in cargo carrying capacity; build her too light and Old Ocean will surely find her weaknesses.

As to the development of speed at sea, the latest results in that direction are most wonderful. The small torpedo boat a few years ago occupied the field for speeds above 20 knots. Now we have the *Minneapolis*, for example, of the United States Navy, an 8000-ton vessel, reeling off 23 knots an hour, and the new torpedo boat destroyers of England are rapidly nearing a 32 knot gait. These small vessels of 230 tons displacement must have about 4500 horse-power. Some of the first of these vessels were built with locomotive boilers, but the later ones all have water tubular boilers of various designs.

A few wiseacres and men whose limit is what has been done, shake their heads when the water tubular boiler is advocated, but the same courage and persistence that have made the triple engine and the high-pressure boiler safe, reliable servants in every-day use, will most certainly develop the water tube boiler and make it the boiler of the future.

The fast ships to come will have this boiler, forced draught and fast running engines. As to the use of new metals for ship construction, steel seems destined to hold its own.

CAN COKE BE USED AS A SMOKELESS FUEL?

By H. W. Spangler.

THE use of any special fuel lunder normal conditions in a well-regulated power plant depends on the ultimate cost of producing steam by its use. This ultimate cost is made up of many items, and among others includes wages, depreciation, sinking fund, cost of repairs, etc., and finally, cost of fuel. Any fuel requiring a large increase in any one of these separate items, although its first cost may be much less per ton than that of some other, will not be voluntarily used unless its steaming power more than makes up for loss in the other items of the expense account.

The emission or prevention of smoke in such a plant practically will not show on the balance sheet, and generally it is only when the prevention of smoke can be accomplished at no expense to the owner that it can be accomplished at all. The only cases in which this is not true are where public opinion has forced the adoption of laws to reduce the emission of smoke, or where additional expenditure for fuel is justified by business reasons not at all connected with the economical development of power, which might be the case, for example, on railroads catering to the comfort of their passengers and thus increasing their business.

Coke is one of the unusual fuels referred to, and its use or disuse must be decided on some such grounds as those above mentioned. The first question to be considered is whether coke can be burned under an ordinary boiler as now constructed, or is it necessary to provide a special class of boiler, with unusual settings to handle it?

Many attempts have been made to burn coke for steam purposes and many of these have failed. There is one case in which it probably will always fail, and unfortunately, this is the case which is most prolific in the production of smoke. Many boilers are entirely too small for the amount of work to be done; the maximum amount of steam must be produced in the minimum amount of space, and additional space is either too valuable to be used for power development, or cannot be obtained at all. The only way in which the owner of such a plant can supply the necessary amount of steam is to burn that quality of fuel which will give the greatest quantity of steam per square foot of grate. This is, in practically every case, soft coal, and, as it must be burned in the most wasteful way, large quantities of smoke result. Coke cannot be burned under these conditions at all, and nothing but rigorously enforced laws will abate the smoke nuisance.

In almost every other case coke can be burned in an ordinary furnace and with ordinary appliances. The oldest recorded successful attempts were made at Vienna and some of the results are interesting. These have been referred to at some length in a paper on the subject in the *Journal für Gasbeleuchtung und Wasserversorgung*, in 1886, and from this many of the data here given have been taken. Many attempts to burn coke on coal grates having small furnaces and slight draft were not successful, and attempts to use it in locomotives soon led to burnt out copper

fire boxes and grates; where success had been obtained it seemed to be accidental. When coke was successfully burned, no injurious effects of any sort were produced on the boiler, and records have been kept of stationary boilers in use twenty-five years and locomotives for twelve years burning coke successfully.

Tests of small boilers using coke have given fairly economical results. Two such tests from the same authority are here given. The boilers were shell boilers on the order of double-decked, plain cylinder boilers, with three or four passes of the gas, each boiler having a separate small stack.

Heating surface	107 to 118 sq. ft.
Grate surface	6.4 to 7.5 "
Stack height	26 to 33 feet.
Stack diameter	1 to 1.1 "

The tests showed:—

Heat accounted for in steam	61.7 per cent
Chimney gas takes off	10.5 "
Temperature of chimney gas	473 F.
Air used 1.2 times theoretical.	
Damper nearly closed.	
Loss between grates	9.6 per cent
Radiation, etc.	18.2 per cent
Coke burned per sq. ft. of grate per hr.	9.8 lbs.
Water evaporated per pound of coke under the conditions of use	6.8 "
Boiler horse power	21

Other tests on the same boiler showed that from 13.5 to 16.2 pounds of coke could easily be burned per square foot of grate.

In the case of a larger boiler the results were even more favourable to the economy of the fuel. The following are the results:—

Heating surface	485 sq. ft.
Grate surface	15 "
Flue area	1.6 "
Height of chimney	56 ft.
Coke burned per sq. ft. of grate	9.8 lbs.
Water evaporated under the working conditions per pound of coke	8.5
Chimney temperature	446 F.
Air supplied 1.4 theoretical required.	
Ash (having 28 per cent. combustible)	3.94 pr. ct.
Chimney losses	11.3 pr. ct.
Boiler efficiency	75.5 pr. ct.
Boiler horse power	41.5

The tests of these boilers show that on boilers of small size coke can be satisfactorily burned and with fair economy, but that boiler capacities are probably reduced.

Tests made in the United States have confirmed these results. The burning of coke on locomotives has been practised by the Baltimore and Ohio Railroad for many years. All their passenger engines running into Philadelphia burn it successfully. A very small quantity of soft coal is added to it in use, the amount being greater in winter than in summer.

But few changes were required to fit the locomotives to burn coke, and the results of firing it have been entirely satisfactory. The coke is screened and the smaller coke is burned in stoves, or is sold. The cost of burning it is probably in the same ratio as the costs of coke and coal given hereafter. The smoke nuisance is practically done away with by its use, and in large cities all shifting engines, at least, should be required to burn either coke or anthracite. To handle the coke properly is no more difficult than for a hard-coal fireman to satisfactorily handle soft coal. These attempts to burn coke point to the following results:—

As coke is very largely carbon, it requires as much, and often more, air per pound of fuel to actually burn it, and eighteen to twenty pounds of air were required for coal, while twenty-six to twenty-eight pounds were found necessary per pound of coke. The fuel bed must be kept deep or it will be found impossible to maintain the steam pressure, and that no fire is more difficult to bring to its proper condition after it has once become low has been the result of the experience of every one using coke. As the latter will make a heavy clinker, the draft must be very strong after a fire begins to get dirty.

The valuable heating surface in a coke-fired boiler is that directly over the fire, as the gases will not carry flame, and these tests have shown that after leaving the fire chamber proper, fifty per cent. of all the heat had been taken up.

The heating surface then can be smaller and the grate should be larger than ordinarily made for coal, which largely accounts for the reduced capacity obtained on trials.

About two-thirds as much coke as coal can be burned per square foot of grate in ordinary running. Grate openings must vary in width with the size of coke used; if the openings are 0.3 to 0.4 of the entire grate area, they are

sufficient to admit the proper quantity of air, and it has often been found necessary to water cool the grates. Boiler plates must be kept cleaner on the water side over the fire to prevent the plates or tubes from burning with the intense flame.

This experience has shown that no injurious effects are produced by the use of coke. Shell boilers have been fired entirely with coke and have been in use from 1855 to 1890. At the Berlin Gas Works two fire-tube boilers have been in use since 1880.

When burning mixtures of fine coke and anthracite, wart-like deposits have been found to form on the tubes of water-tube boilers which become large masses if not cleaned away. These excrescences are, however, easily brushed off, leaving the tubes clean and smooth.

It seems, therefore, that for stationary purposes coke can be used for steam producing with the limitation stated above.

The stationary boilers of which tests were given were fired with gas coke, having the composition given below, while the locomotives referred to burn coke having the composition shown in the second column. This comparison shows that practically the same material has been used in the two examples cited.

	Analyses of Coke above	Connelsville Coke.
Carbon	83.4 to 89 per cent.	87.5 per cent.
Hydrogen	.14 to 4.11 "	
Water etc.	.9 to 5.6 "	.5 per cent.
Sulphur	.34 to .64 "	
Ash	8.05 to 9.56 "	11.32 "
Heating Value per pound	12250 to 13100	12660. "

There seems to be no difficulty, therefore, in burning coke in either stationary or locomotive boilers if there is sufficient boiler capacity available.

The question of cost is the next one which presents itself for solution in connection with the matter after deciding on the possibility of handling the coke. From the tests above cited it would appear that for the same capacity, additional boiler plant would be required to do the same work. As to the probable cost of the fuel itself, valuable data can be obtained from the various reports of the late Joseph D. Weeks, in the "Mineral Resources of the United States," and the data given further on are made up from these reports. These cover only what is known as furnace and foundry coke and do not apply to the coke from gas works, from which in the future, as at present, a large amount of coke will be obtained.

The relative value of coal and coke for steam making can be determined from its composition and cost. Taking the Connellsville, Pa., coal and coke as a basis of comparison, we have the following analysis:—

	Coal.	Coke.
Water	1.13	.49
Volatile	29.81	
Fix. carbon	60.42	87.46
Sulphur	.69	.69
Ash	7.95	11.33

These analyses give in the neighbourhood of 13,860 heat units for the heating value per pound of coal and 12,660 per pound of coke. That is, to be of the same steaming value as a pound of coal, coke should be bought for 0.91 as much as coal per ton.

The relative price of coal and coke per ton at the ovens are given in the table below from the last two years as the average for Pennsylvania:—

	Coal.	Coke.
1894	$0.586	1.086
1895	0.616	1.266

There is, therefore, no economy in burning coke when it costs in the same proportion as at the coke ovens. That is, if one attempted to burn coke in 1895 his fuel cost per pound of steam would be more than double what it would have been had the coal been directly fired. At a distance from the source of supply the difference would be still greater, because of the difference in freights.

In using gas coke the conditions are not the same. The coke in that case is a by-product, and, as we have already seen, can be used for steaming purposes as well as the other class of coke.

In a city, like Philadelphia, for example, using about a million tons of bituminous coal per year, about one-fourth is used in the city gas works. The use of bituminous coal is increasing, while at present the amount used for gas making is not increasing in any-

thing like the same proportion. In 1896 about 313,000 tons of soft coal were used in Philadelphia for gas making; 8,563,290 bushels of coke were made, and of these 3,826,933 bushels were sold to consumers. The balance was used by the city. The coke sold, of course, was largely used for household purposes and replaced the more costly anthracite, as soft coal is but little used for domestic purposes. Whereever much soft coal is used for domestic purposes, there is no reason why coke should not be used instead, as it will be found to be but little, if any, more expensive.

In addition to the coke, 1,532,395 bushels of gas house breeze were sold. This is probably the cheapest fuel to be obtained at any distance from the mines. It is very fine and has the appearance of soft coal slack, or screenings, with a few larger pieces of coke scattered through it. It has been found desirable, in using it, to mix it with fine anthracite coal, and the mixture can readily be burned on an ordinary grate such as is suitable for buckwheat anthracite. It is not entirely smokeless, but it produces much less smoke than bituminous coal, and this smoke lasts only a few minutes after firing. It has been used with water-tube boilers, return tubular boilers, and internally-fired shell boilers, and as soon as the fireman becomes used to firing it, it gives entire satisfaction.

Such fires require closer attention than those using coal alone, and with a constant demand for steam a little neglect on the part of the fireman soon reduces the pressure. A very heavy clinker is formed and fires must be cleaned frequently.

The average fuel cost of one thousand pounds of steam from and at 212 degrees F. with anthracite buckwheat costing \$2.20 (£0. 8. 10.) per long ton delivered was 12.90 cents (about 6½d.), while using the same quality of coal, mixed half and half with gas house breeze, gave 9.38 cents (about 5d.) per thousand pounds of water evaporated.

The water evaporated from and at 212 degrees per pound of fuel fired was 8.38 pounds with the mixture, and 7.85 pounds when using the buckwheat coal alone. These results are the average of a number of trials. The chemical composition of this breeze is as follows, and its heating value is high:—

Moisture	1.19 per cent.
Volatile	13.66 per cent.
Sulphur	2.02 per cent.
Fixed carbon	75.68 per cent.
Ash	7.45 per cent.
Heating value	14080 B. T. U.

It has been possible with the mixture above referred to, to develop the rated capacity of the boilers; thus, with boilers aggregating about 1000 nominal horse-power, that is, with from 10,500 to 11,000 square feet of heating surface, an average of 930 horse-power has been obtained for the entire twenty-four hours with a maximum, probably, of 1050 horse-power.

It will thus be seen that while coke can be burned efficiently under boilers as long as it is made as a first product, it cannot be burned economically. As a by-product it can be economically used for fuel purposes, but the supply is so limited that it can fill but a small portion of the field now filled by smoky fuels. With sufficient boiler power available, the small coke or coke breeze will be found to be probably the most economical fuel that can be obtained and produces much less smoke than soft coal.

THE DANGERS OF TALL STEEL STRUCTURES.

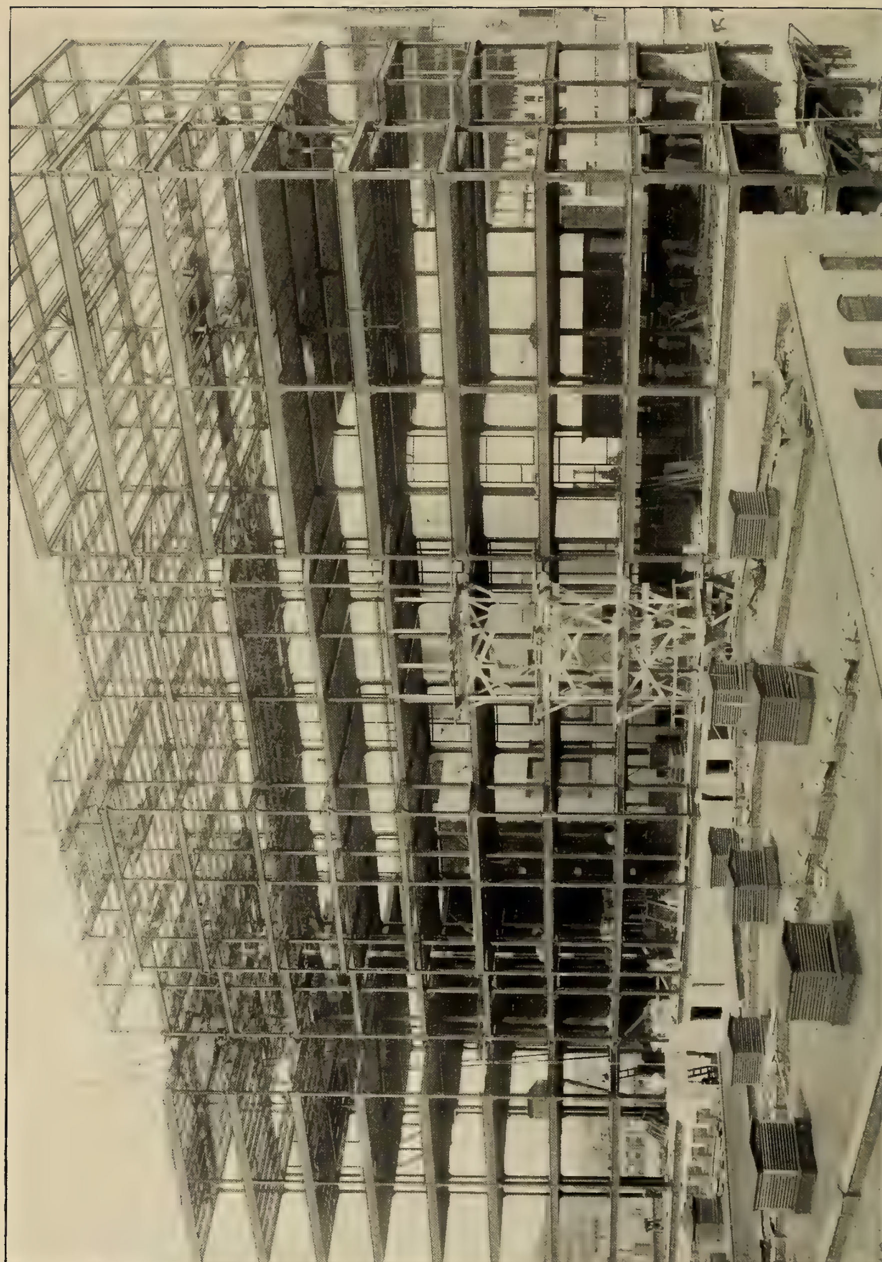
By W. L. B. Jenney.

IN the putting up of steel structures of the tall office building type which, in recent years, have become so common in the large cities of the United States, there are no dangers that an experienced architectural engineer cannot so guard against as to remove all and every cause for uneasiness; yet there are dangers that, from carelessness or want of skill, might easily become frightful. A tall, steel skeleton building is a scientific structure, in which every piece of steel and even every rivet can be accurately calculated from known data. All the strains of load and wind pressure can be determined and provided for with as much accuracy and certainty as in a railroad bridge.

In considering the dangers in detail, the foundations are, naturally, first to be considered. If the building is erected on rock or on an incompressible soil, it is essential that the building should remain where placed, or, if built on compressible clay such as underlies some places and where settlement is unavoidable, the loads must be distributed with such uniformity that the settlements shall be substantially uniform. The total settlement should not be excessive. It can be usually limited to two or three inches.

The steel in the foundations should be heavier in the web than the calculations actually demand, as a safety against any possible injury by rust. Every precaution, however, should be taken to prevent any injury to the steel. The latter should be painted two coats. The paint should be elastic, so as not to crack or scale off by the expansion and contraction of the metal, and it should not dry out, harden and crumble. There are several good paints in the market,—from the best old red lead and linseed oil, and also graphite paints, that have long been in use, to some of the new ones that promise well. But they must not be left to the selection of the contractor, who naturally will spend as little money on them as practicable. The architects must select what he considers the most lasting paint and see that it is used, and also that it arrives at the building in sealed packages, direct from the manufactory.

Then the steel should be imbedded in strong Portland cement concrete, well rammed into place, and the surface should be troweled smooth and hard, using mortar composed of equal parts of Portland cement and clean sharp sand so as to be impervious to water. This concrete is itself an excellent protection to the steel, both against fire and against rust. Apprehension was raised not long ago by an eminent engineer, at a convention of a prominent engineering society, at which he stated that in the anchorage of the cables of the Niagara Suspension Bridge, which are imbedded in concrete with a limestone aggregate, the rust had eaten deeply into the steel wherever the limestone had come in contact with the metal. As a matter of fact, however, the limestone is inert and the statement was pronounced an error, as there was no corroboration of it. Not long ago an opportunity was offered in Chicago to examine steel rods that had been buried



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THE STEEL FRAME OF THE HOTEL ROYALTON, NEW YORK. MESSRS. ROSSITER & WRIGHT, ARCHITECTS, NEW YORK.

in limestone concrete for about eight or ten years, and the steel in that case was entirely without injury.

The foundations of a tall building must not only be immovable after a reasonably short time, but must remain so. There should be no probability that after a period of years, decay by rusting of the steel or other injury can possibly occur.

One of the greatest dangers to tall buildings is from the excessive wind pressures from a cyclone. What pressure a cyclone may exert on the side of a tall building has not yet been fully determined. All observations have been made on small surfaces, usually not exceeding one square foot in area. It is generally admitted that the total pressure on large areas is not in proportion, that is to say, the pressure on the side of a building measuring 50 × 150 feet, or 7500 square feet, is not 7500 times the observed pressure on a single square foot, but is materially less.

It is usual to provide against a wind pressure of 40 pounds per square foot over the entire area exposed, using a fibre strain of 16,000 pounds on the steel, while a pressure of 80 pounds, or more, may be exerted on a single square foot for a short time. It is not probable that on the large surfaces of a tall building the total pressure would be so great as to run the fibre strain up so high, for the short time during which these great pressures continue, as to become actually dangerous. The disastrous St. Louis cyclone in the United States about two years ago did not strike any completed steel structure, so that no practical tests exist of a tall steel structure subjected to a severe cyclone.

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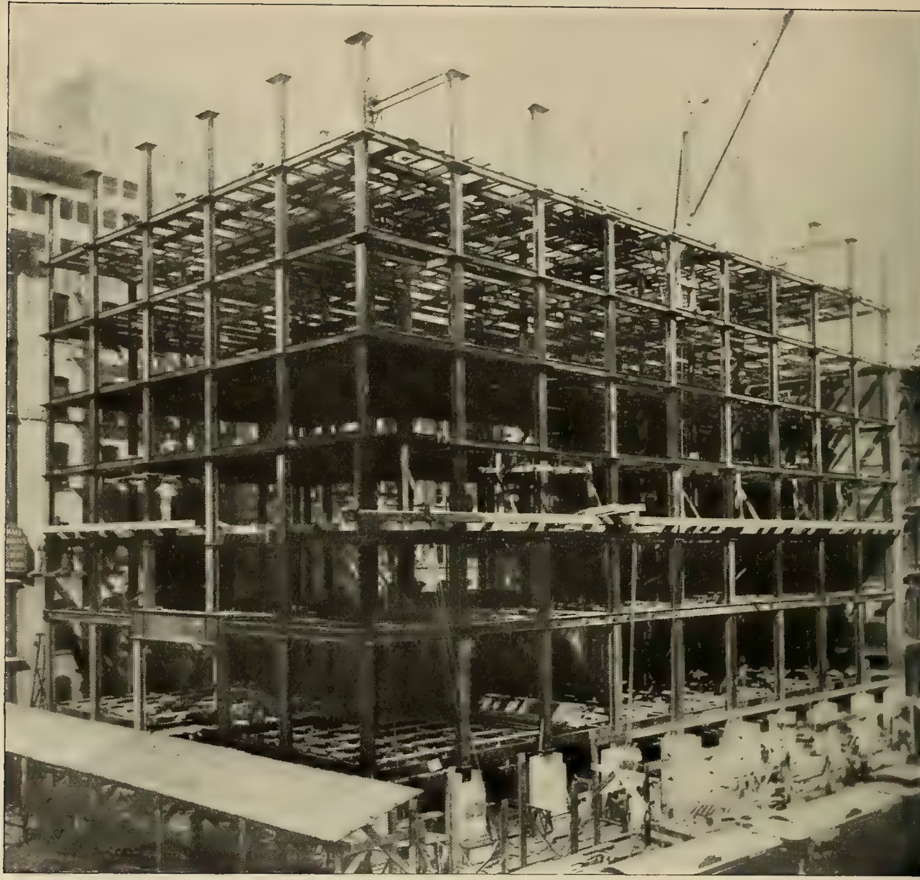
FOUNDATION PIERS FOR A THIRTY-STORY OFFICE BUILDING.

The Home Insurance Building, in Chicago, was on one occasion struck on its long side by a wind sufficient to blow in some of the window sashes and the plate glass in some large, single light, bank windows, but the building was not otherwise affected in any manner. The writer was in the building at the time, but did not notice any jar or vibration, nor did the draughtsmen, with their pencils on the paper, in his



A CONSTRUCTION VIEW OF THE NEW YORK LIFE INSURANCE CO.'S BUILDING, NEW YORK.
MESSRS. JENNEY & MUNDY, ARCHITECTS, CHICAGO.

draughting room, which is on the eleventh floor, in a long wing, particularly exposed. But the squall was not as severe as the one in St. Louis.

In Chicago there are two very long buildings, forming one block, known generally as the Monadnock Block, which is really only the north half of the block.

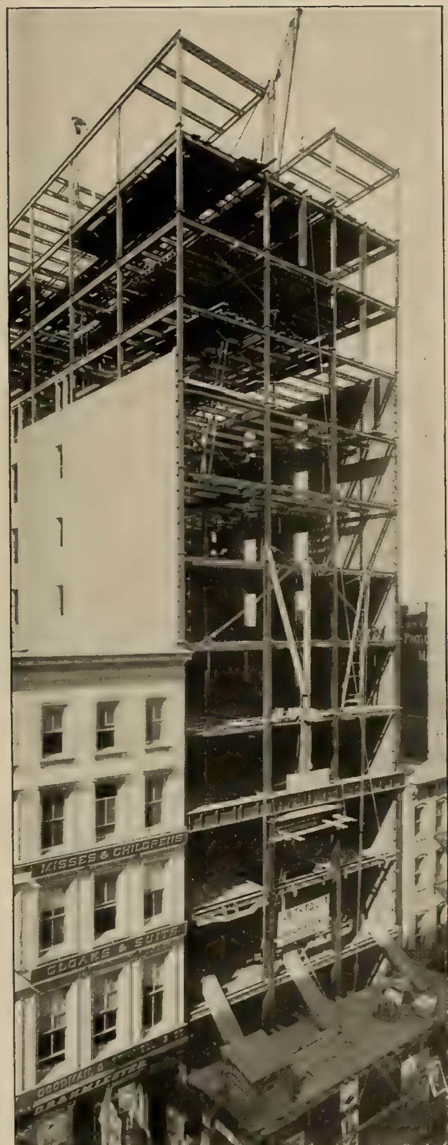
This north half is of old-fashioned fireproof construction, that is, heavy masonry walls, several feet in thickness; the south half of the block is of steel skeleton structure. This long block is only about 63 feet in width. The long side is to the east. It is sixteen stories high, with pent houses on the roof, fully equal to another story. About three years ago there was a very heavy gale blowing from the east, square against the long side of the building. The agent, who was anxious to know how the building would behave under such circumstances, called in several experts to estimate the vibration. They reported that the extreme movement of the cornice was $\frac{3}{8}''$ in either direction from the perpendicular and was more pronounced in the old-fashioned heavy masonry wall construction in the north half of the block than in the light steel skeleton forming the south half. This is as one would naturally expect. The steel skeleton, being riveted together and braced in every direction, is more rigid than masonry walls that rely solely on their weight for their stability.

It is best to make the connections of floor beams and girders to the steel columns with $6'' \times 6''$ angles, with four

rivets in each leg, instead of the standard connections of $3'' \times 3''$ angles with two rivets in each leg. By the rigidity of the connections a material proportion, often 25 per cent., of the wind pressure can be provided for. The balance is taken by the exterior steel. The connections being stiffened by gusset plates, the sections of the columns are increased to resist the bending moment in the direction of the pressure. As the fibre strain used in the calculations is only 16,000 pounds, giving a coefficient of safety of about four, it can easily be doubled for a short period with perfect safety, as the ultimate is never less than 65,000. The maximum wind pressure that may reasonably be expected to occur, is, therefore, amply provided for, and the greatest danger is removed.

In a store building where there is a large stock of inflammable goods, such as dry goods or groceries, the inadequacy of the fireproofing becomes a source of danger. A great fire, which occurred in the city of Pittsburgh last year, demonstrated that there is much room for improvement in the fireproof material and in the method of putting it on. About one-half of the steel in that case was stripped and left naked, and the lower flanges of many of the floor arches were scaled off. The steel made an excellent showing. The injury to the metal under the very trying conditions of that fire was estimated by the appraisers to be only about 2 per cent. of the whole, not considering the accident of a 25-ton closed steel elevator tank that fell through the building from roof to first floor, an accident that, now the danger is known, never need occur again.

The material for fireproofing should be what is known as porous terra cotta, made by adding six volumes of sawdust to four of clay. On burning, the sawdust is consumed and a tile is produced that is full of air holes, or little cells, rendering it impossible for any hurtful heat to penetrate to the metal. The usual practice of laying fireproofing in lime mortar is to be condemned as weak and insufficient. Strong Portland cement mortar only should be used. It is well to add sufficient lime mortar to cause it to work freely under the trowel. A good proportion is, equal volumes of



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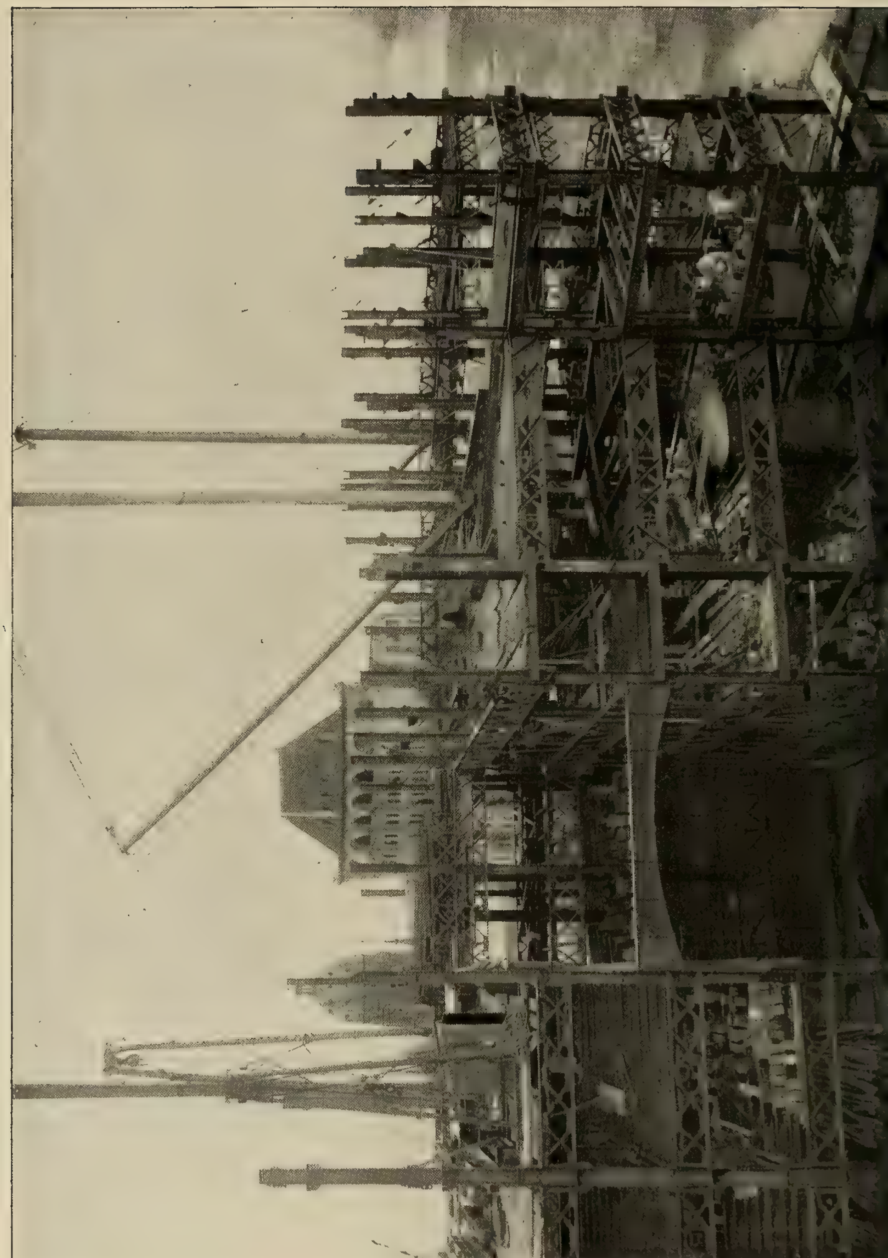
A TWELVE-STORY WAREHOUSE. MESSRS. CLEVERDON & PUTZEL, ARCHITECTS, NEW YORK.

best lime mortar and of one of the well-proven Portland cements, thoroughly mixed at the time of using. No inferior or untried material should be employed.



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A CONSTRUCTION VIEW OF A THIRTY-STORY OFFICE BUILDING ON PARK ROW, NEW YORK. R. H. ROBERTSON, ARCHITECT,

The fireproof material should be tested by heating it to bright redness and plunging into cold water, repeating the experiment several times. If the material is seriously injured by these tests it should be discarded as worthless.

In laying the fireproofing, every opportunity should be taken to anchor it together and to the metal. As often put on, there is no protection against the shock of the water in case of fire, and, as in the Pittsburgh fire, a large proportion is stripped off as soon as it is struck by the first water. Particular attention must be given to the protection of the lower flanges of the beams and girders. The architect should design the fireproofing, and show the shapes and the anchorage. The use of cinders concrete must be condemned, as the cinders perish in a fierce fire. An aggregate composed of broken waste, fireproof material, or crushed blast furnace slag is far better and very satisfactory. None but Portland cement mortar should be used. The fireproofing should be the very best that the ability of the architect can devise and the fireproofing contractor execute. This is no place for economies that reduce quality, either in material or workmanship. None but the very best is worthy of consideration.

As to partitions, the Pittsburgh fire demonstrated that four-inch tile partitions blew away into dust when struck by the water. The firemen testified that they seemed to melt away, and as a matter of fact, little débris of disturbed partitions was found after the fire. A substantial partition can be made of T iron supports, well secured at top and bottom, and filled with concrete with twisted iron rods imbedded in it, on the plan of what is known in the United States as the Ransome system. This Ransome system is more than a fireproofing; it is a system of construction. It is described in a recent book by Kidder—"Building Construction and Superintendence, Part I."

The report of the adjusters of the Pittsburgh fire, employed by the insurance companies, in speaking of the Methodist Book Concern building, in Pittsburgh, where the concrete system had been used, and which was scarcely injured, although everything combustible was consumed in the building, stated:—"The fire resisting qualities of properly made concrete have been amply proved to be equal, if not better, than fire clay tile, as shown by the series of tests carried on by the Building Department of the City of New York."

In the Pittsburgh fire every particle of combustible material perished. The amount of such material in the construction of the building should be reduced to the minimum, particularly in a store. The base and the casings of all openings should be of concrete or metal. They can be as ornamented as desired. The wainscot should be either of cement or marble. Floors should not be of wood; concrete is recommended. Doors should be of metal. All stairs should be of iron. The treads may be of marble.

If there are any combustible buildings in the vicinity, near enough to be a menace, the openings either on alleys or on street fronts should be protected by fireproof shutters. Those of street fronts can be made to roll up into a pocket in the window head so as not to be a disfigurement. At the Pittsburgh fire, again, the rear shutters in the building, which were nothing more than wood covered with tin, stopped the fire and prevented much loss; without these shutters the fire would have spread into an adjoining theatre building and no one knows where it would have stopped.

Until recently all the known plasterings were utterly destroyed in case of a very serious fire. They offered no protection to the lath or to the fireproofing. There is now on the market a new plastering made of asbestos mixed with lime, known as "Asbestic," that, from personal knowledge, seems very promising. The reports of experiments state that it adheres firmly to any material on which we usually plaster and resists the fire completely, and that thus far none of it has ever been washed off in experimental fires. It is not only itself preserved, but it protects all that is behind it and is a valuable assistant in

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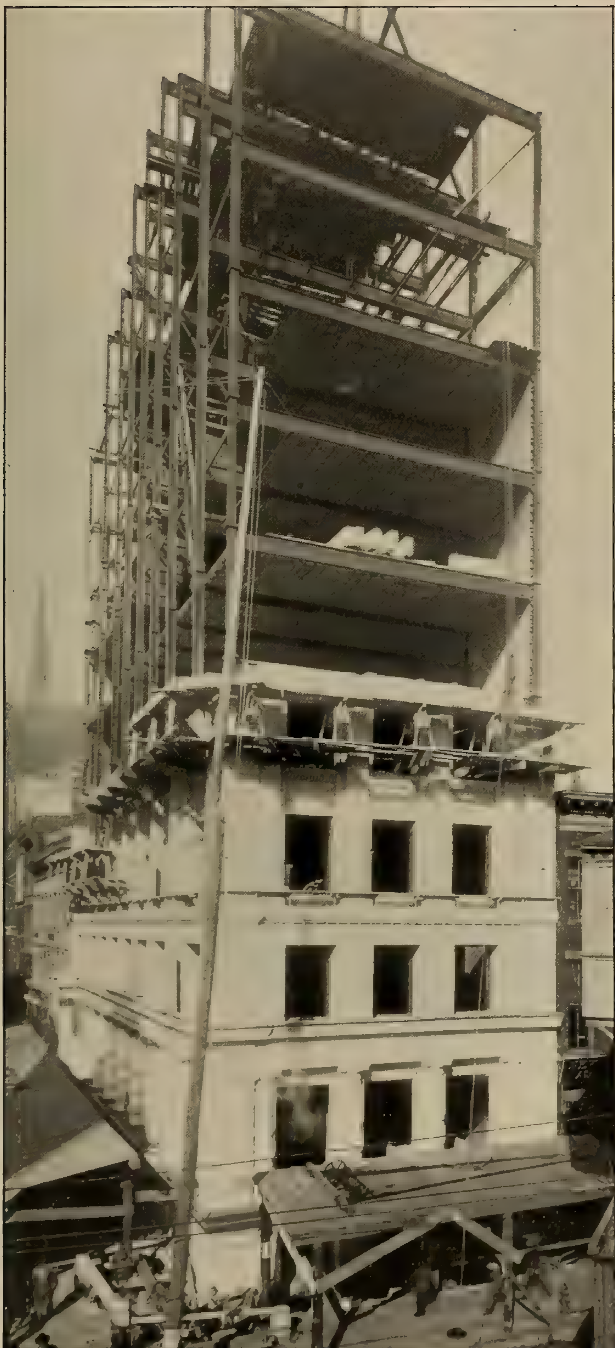
THE R. G. DUN BUILDING, NEW YORK. MESSRS. GEO. EDW. HARDING & GOOCH, ARCHITECTS, NEW YORK.



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THE MECHANICS' BANK BUILDING, BROOKLYN, N.Y. GEO. L. MORSE, ARCHITECT.

holding the fireproofing in place, which is a very strong recommendation. The cost of this material on the walls is said to be no more than any of the good plasterings generally in use.

One of the dangers in a big store is due to the extensive area covered by inflammable goods. Substantial division walls, with a minimum number of openings, protected by fireproof doors, materially lessen the risk, as it is quite possible then to confine a fire to one compartment. In the wholesale business this sub-division offers no difficulties. In large retail stores, however, it materially injures the effect, and is so much objected to that an owner is rarely willing to admit the cross walls, claiming that through them he loses all the benefit derived from the big store, and that many of his customers come there originally simply to see the fine display, and then make purchases. Against these arguments, of course, there is nothing to say.

Lightning is not dangerous to the steel skeleton building. The entire skeleton, in fact, is a lightning rod of the most efficient type. It is closely riveted together, forming a continuous rod; the steel columns extend through the basement to a broad steel foundation, below the basement floor, and are usually in a damp soil.

The iron water pipes in the building, too, are connected with the iron street pipes of the city water supply, which form a very effective ground connection. The same is true of the gas pipes, so that in the way of protection from lightning nothing is left to be desired. The Home Insurance Building, in Chicago, was struck by lightning on one corner some time ago, but the only injury was the displacement of a few bricks where the lightning entered the cornice to reach the steel, through which it was taken off harmlessly. There is no record of any person ever having been injured by lightning when in a steel or iron frame building, or when on board of a steel or iron ship.

Earthquake effects on tall buildings have always been matters of interested speculation. The native hut in the Malay Archipelago is the one building that is never injured by an earthquake. Its construction closely resembles the steel skeleton in its general engineering principles. Posts are set in the ground and the skeleton framework is all notched and lashed together. The exterior is simply a covering to keep out the weather. The steel skeleton is much like a bird cage, firmly riveted together at every joint, so that the shaking of an earthquake might shake off some of the exterior masonry, but could not injure the building nor its inhabitants.

In building in an earthquake country, special precautions should be taken whereby any injury, either external or internal, could be entirely avoided, and one of these tall buildings would be as safe as the middle of a ten-acre lot. The extra earthquake precautions are neither difficult nor expensive. They consist in putting in additional ribs in the partitions and external walls to which the masonry is firmly anchored. In such a building all the partitions should be of concrete, with steel rods imbedded in it.

A building constructed as herein outlined would be fireproof, cyclone-proof, lightning-proof, and earthquake-proof.

THE AMERICAN NAVAL OFFICER OF THE FUTURE.

A Fighting Engineer.

By Walter M. McFarland, P. A. E., U. S. N.

EARLY in November of last year, the Secretary of the United States Navy organised a board of officers, with Assistant Secretary Theodore Roosevelt as president, for the purpose of considering measures calculated to promote harmony and increase efficiency in the naval service with special reference to the Line and Engineer Corps. The board was composed of seven line and four engineer officers and may be considered fairly representative of the two corps, a majority of the officers having been in the navy over thirty years, while each side had one officer to represent the younger men, the writer being one of the latter.

As the engineers have for many years past claimed that they were not accorded a proper status in the navy, they were called upon for a statement of their claims, and these were submitted as follows:—

1.—The right to exercise military command over the men of the Engineer Department. It may surprise those who are unfamiliar with naval laws and regulations to learn that such a claim should be necessary; but existing law and regulation explicitly deny the right of command to all staff officers, which includes engineers.

2.—The right, under proper circumstances, to command any enlisted man. At present, with the right of command denied to staff officers, there have been cases in which it was attempted to subordinate a commissioned staff officer to an enlisted man.

3.—Actual instead of "relative" rank, in order that the legal right to command enlisted men should not be questioned.

4.—The military title indicative of this rank, but with the name, Engineer Corps, added, in order that there might be no confusion with officers of the line, and following the custom of the army with respect to officers of the various corps and departments.

These propositions were discussed thoroughly and then the line officers were asked for their views. While some of the propositions were considered with a certain degree of approval, it may be said in general terms that, as a whole, the claims of the engineers met with unanimous opposition from the other side.

It may have occurred to many, at first glance, that the board was not fairly organised, there being such a majority on one side, which would seem, where disputed points were to be settled, to amount to packing the jury. A little reflection, however, and consideration of the well-known reputation for fairness of both Secretary Long and Assistant Secretary Roosevelt, would convince any one that this could not be the case, and, as a matter of fact, the board was not acting as a jury to settle questions by a majority vote, but rather as a number of experts whose opinions were desired on certain important questions. In the order convening the board, Secretary Long expressly directed that on all disputed points the vote was to be by yeas and nays, each member having the right to enter his

reasons for his vote on the record. This assured perfect fairness, and, in fact, gave every officer full opportunity to present his views in his own way.

It might seem that matters had reached a deadlock at the very start, when one side totally disagreed with what the other considered as vital claims; but the solution came in a proposition from one of the line officers, to make the engineers line officers, to abolish the separate corps, and to have all the engineering duty performed in the future by line officers. While it can hardly be claimed that the officer who made the proposition is the originator of the idea, inasmuch as a number of other officers have, to the writer's knowledge, advanced it in past years, still as the one who started the scheme which, if consummated, will make such a radical change in the navy, it is only proper to give the credit to Captain Robley D. Evans. If the proposed plan goes through, he may be called the father of the new United States Navy.

To those who have not watched the growth of the modern battle-ship and the radical change which it has brought about in the duties of the personnel, the idea of abolishing the engineer corps at the very time when the battleship has become a fighting machine, when everything about such a ship is done by machinery, and when the engineer's force has, in some cases, become almost half the crew, may appear not merely radical, but revolutionary, illogical and utterly subversive of efficiency.

This is one of the cases where a great deal depends on names and definitions. It will be observed that the scheme is not one of destruction, but of construction. The engineer corps, as a separate body of officers, disappears, but not its duties. These are, in the future, to be the work of the entire list of line officers, so that instead of about 200 engineers there are to be about 1000, who, however, will not be called engineers, but will retain the old titles of naval officers. In short, naval evolution and the effect of environment have made the naval officer an engineer.

Many critics will, undoubtedly, say that this is simply special pleading and a dealing in generalities. But let us consider what engineering work the modern line officer is compelled to do now! It must be admitted at once that the management and care of turrets for guns of 10 inches caliber and upwards, where every incident of the service of the gun is done by machinery, is engineering work; and any acquaintance with the guns of either the main or secondary batteries must make it apparent that they are machines of considerable complication, the maintenance of whose integrity involves training as an engineer.

The modern torpedo is an intricate machine, whose service involves other machinery also, and, in one navy at least, this has brought out a special corps of torpedo engineers. Then there are the numerous electrical machines; in fact, as already stated, everything in a modern man-of-war goes by machinery. At present, the officers who have to handle and care for much of this machinery are not trained as engineers and they have to learn their duties by the method of trial and error. Those who have natural mechanical aptitude make fewest mistakes and become proficient soonest.

Much of the duty performed by line officers on shore is also engineering work, such as the superintendence of the gun factory at Washington, the inspection of torpedoes, rapid-fire guns, small-arms, and of steel material for various purposes.

It will probably be granted that a thorough engineering training would enable all these officers to perform their duty better, but the point to be noted is that these are now the part of their duties requiring the greatest amount of education, and that consequently they have become engineers in fact, although not in name.

We thus come to the existing state of affairs, where we really have two sets of engineers, whose education is not at present entirely the same, but who, if properly educated, would have so much in common that the part remaining for each to learn is relatively small.

The members of the board, and the engineers most of all, realised fully that this is an age of specialisation, and, so far from running counter to the spirit of the age, they desired to recognise it fully, and to organise the personnel of the navy in accordance with it. When we talk of specialisation, we must realise that the Navy itself is a very marked case of it. Its sole *raison d'être* is to be in the highest state of efficiency for fighting, and, omitting for the moment the medical and commissariat departments, the two things of supreme moment are the manipulation of the weapons of destruction and of the motive power, both of which mean the command of large numbers of men and engineering training.

In the navy of the future, as sketched by the board, every officer is to be competent for duty in either of these fields. He is to be an engineer who is competent to care for and manipulate any of the engines on board ship, and who has been trained to command the men who actually handle these various engines. He is a specialist, who has been given careful training for the particular work he has to do, which is different from that coming on any other engineer; he is, in short, a fighting engineer.

The statements thus far made assume that the new line officer is to be given a thorough and appropriate training for his enlarged duties, and this was carefully discussed by the board, which had the superintendent of the United States Naval Academy in consultation. The necessary curriculum was not embodied in the bill because it is a matter of administration, properly coming under the executive duty of the Navy Department, but it will be provided, just as, in the past, changes have been made to meet the requirements of improvement in science and the arts connected with naval matters.

It may be objected that a great deal is being demanded of the future line officer, and that it will be difficult to get men who can fulfil the requirements. Mr. Roosevelt, in his report to Secretary Long, discussed this point very thoroughly. He admits frankly that the requirements of the future line officer are great, but maintains that history shows similar problems in the past to have been solved and gives the assurance that they can be in the future. Just as the fighting sailor, typified by Nelson, had to know a good many things which were unknown to Blake, his great predecessor, so, Mr. Roosevelt maintains, the Farragut of the future can justly be required, with the progress of events, to know much of which the American hero was ignorant. Indeed, there are doubtless many engineers, who served in the late American Civil War, who will agree that, if the commander of the ironclad fleet off Charleston had been trained as it is now proposed to train future commanders, the results there would have been very different.

As was stated in the beginning, the board was to consider means of increasing harmony and efficiency. It is a melancholy fact that, in the past, there has not been that harmony in the United States naval service which ought to exist if the best results are to be obtained. This does not mean that the personal relations of officers were always strained. Indeed, some of the warmest personal friendships in the service are between officers of the two corps, but even these have not always availed to prevent official friction. The engineers have felt that they were not accorded the official standing which the importance of their work demands, and this has had the effect of making many of the ablest of them ready to consider offers from civil life, and a number have resigned, who could not well be spared, and who, for the best interests of the navy, should have been induced to remain. The scheme which is now proposed gives all that the engineers have ever asked in the way of proper status, and, by joining into one homogeneous body the two corps which formerly had so many points of difference, all grounds for friction will be removed, except such as would be entirely in the nature of personal squabbles.

It may well occur to the thoughtful engineer outside of the navy that, al-

though the new scheme will certainly assure harmony and increase the efficiency of that part of the machinery connected with guns and other weapons, it is not so certain that the integrity of the motive machinery will be as well assured as under existing conditions. This idea would be based on the fact that, except to a man with a natural fondness for machinery, work in connection with the motive machinery would not be so attractive as that on deck, where the officer is much more *en évidence*, and where there are not so many disagreeable features as the conscientious performance of duty below makes inevitable. If this were likely to be the case, the new scheme would certainly decrease, instead of increasing, the efficiency of the Navy. The writer believes, however, that if the whole of the "new line" enters honestly and zealously into the spirit of the new scheme, the motive machinery will be at least as well cared for as at present, and probably better.

Probably few engineers outside of the navy have any idea of the great influence on the efficiency of the machinery possessed by the commanding officers and commanders of squadrons. Speaking generally, no work of repair or overhauling can be commenced without their approval. It need hardly be stated that, as a rule, they are anxious that the motive machinery should be kept in a state of perfect efficiency; but, owing to their lack of engineering training at present, it has happened that they have not always been willing that work should be done at the proper time, and there have even been cases where they have deliberately given orders which caused actual deterioration.

Under the proposed plan, when every officer will be an engineer, such things will be impossible. The future commanding officer will have been in charge of the motive machinery not many years before his promotion, and will understand it just as thoroughly as that one of his subordinates who may then be in charge. He will realise the practical import and significance of every recommendation, and, in addition, will be able to know whether everything necessary is being done, which at present, of course, he cannot.

With respect to the personal and professional interest taken by the younger officers, who will have the detailed work of carrying out the routine of repairs and inspections, the writer believes that those who think this duty will not be zealously performed overlook the fact that these "line officers of the future" will be engineers who have been trained for this work, and not simply sailors who are "playing at being engineers." Every man worthy of the name, tries to perform creditably the work of his profession, the disagreeable parts as well as the agreeable ones, and it is only fair to assume that the naval officers of the future, engineers by training, will properly care for the motive machinery, which is the very life of their ship, and any lessening of whose efficiency means helplessness and disaster.

Thus far the subject of efficiency has been considered entirely from an engineering standpoint; but this is only a part of the question. While there can be no doubt that the duty of commanding the men of the engineer department in time of battle is as truly combatant as any other command, it is just as true that, unless the battery is properly commanded, there can be no fighting. It is a fact that on the larger new ships of the United States Navy there are not enough officers to command properly all the divisions of the battery. The number of officers sufficient for navigating duty is not adequate to this more important work.

Under the new scheme, the officers who stand watch in the engine room during cruising are equally competent to command the battery, so that the complement of officers will provide adequate numbers for duty as watch officers, both in the engine room and on deck, during long cruises, and will also man efficiently all the battle stations in both departments, when everybody is on duty at the same time. Added to this, every officer would be available for duty with landing parties, work which the Navy is often called on to perform.

The credit of the actual suggestion of the plan of reorganisation has been given, but a discussion of the subject would be incomplete without stating that, in all probability, the real author of the movement is Professor Ira N. Hollis, of Harvard University, formerly one of the ablest engineers in the United States Navy. Convinced by his own experience as an engineer officer of the importance of radical change in existing conditions, he brought the subject to the attention of Secretary Long and Assistant Secretary Roosevelt, and submitted for their consideration a scheme which was a long step in the direction of the one adopted. By his able presentation of the subject he interested these gentlemen in this method of solving the problem which had attracted their serious thought from the very beginning of their administration; and the discussion of his plan throughout the service, undoubtedly prepared the minds of officers for the reception of the more radical change which is now proposed.

While the new scheme gives the engineers all that they have been asking for many years, most of them have a feeling of regret that the change involves the loss of the name of engineer. To their claim for a military, in addition to the professional title, the reply has often been that this was a desire to "strut in borrowed plumage;" but the answer to this is that, so far from desiring any weakening of the bond with the great family of engineers, the claim for a military title in addition is to give engineering its proper rank in the navy. As long as the engineers in the service have only relative rank, without the title which shows on its face that the possessor is a military officer of the government, engineering in the navy is not accorded its true place. Every engineer, whatever his special line of work, must feel proud of his professional title, and of being a member of a profession which has done so much for the world, and which has made the difference between the nineteenth century and the centuries which preceded it. It is only natural, therefore, that the present engineers should look with regret on the loss of their professional title. But, in the "Navy of the Future" engineering is to have its rightful place, and is to make American officers masters of the great ships which they are to handle, and thus make these ships still more efficient as the representatives of their country in every sea.

FORTUNES IN NUGGETS OF GOLD.

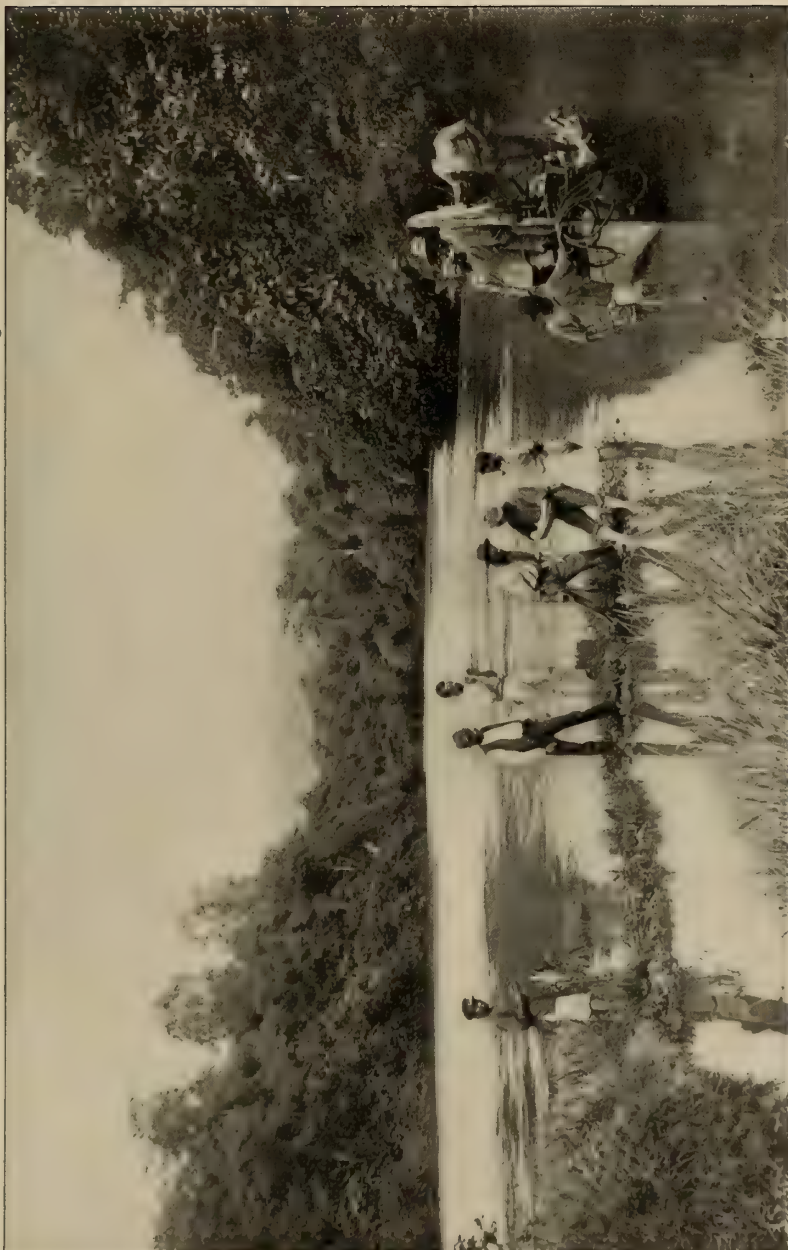
By George Ethelbert Walsh.

IT is not every miner who is lucky enough to find a nugget of gold that represents a small fortune in itself, nor are there many mines that ever contained such huge lumps of the precious metal; but, scattered here and there throughout the world's great mining regions, remarkable nuggets of gold have occasionally been picked up to astonish and electrify civilisation. There is something so romantic in finding a single lump of metal worth thousands that people like to read the story of the discovery many times over, and to cater to this weakness of human nature there have not been wanting those who could invent as good a tale as was ever told. But it is not necessary to drag in the mythical or semi-mythical stories to attract the attention of intelligent hearers; there are plenty of well-authenticated accounts of mining valuable nuggets of gold to suit the most exacting.

Just at present this interest in valuable gold finds is intensified by the excitement over the new gold fields of the Klondike, not because any nuggets of special importance have been found there, but because of the general belief that, when the placer miners have gathered up all the fine gold washed out on the surface, solid nuggets will be brought up from below with the pick-ax and scoop. The placer miner is content to find his gold in small pieces in the dirt which he washes from the surface of the ground; but the general miner who digs down into the bowels of the rocky earth is ever on the alert for nuggets. He knows not at what moment he may stumble upon a huge lump of the precious metal that will reward him for all his labours. It is hard to imagine the joy and feverish excitement that possesses a miner when he kicks out one of these yellow lumps. More than once in the tragic history of gold mining have miners gone mad over the sudden discovery of a huge nugget—a good fortune that they were unable to stand after years of hard labour and baffled hope. It is not to be wondered at either, for a lump of gold as big as your head is a pretty sight. Nuggets are nearly always of great purity, and contain little quartz, so that they give the finder an idea of what they are before they are washed and smelted.

In the great mining days of California, in the fifties, it was a common thing for miners to pick up huge nuggets of gold. They varied in size from a pea to a peck measure. Often they were picked up in gravel beds, and along the banks of streams where no other signs of gold could be discovered. Several huge nuggets have thus been picked up, and the news has attracted hundreds of miners to the spot; but after camping for days and weeks on the place they left, confident that no other traces of gold existed in the vicinity. This peculiarity in the distribution of gold nuggets outside of typical gold mining fields is accounted for by the fact that they have been washed down at some time by the floods and freshets. Thus a large nugget might be dislodged from its original position by a mountain torrent, and carried thousands of feet away.

The largest and most valuable nug-



PROSPECTING FOR GOLD IN NEW GUINEA.

get of gold ever found was discovered in Australia, in 1852, and it was reported to weigh 223 pounds and four ounces, and was worth about £11,000. No authenticated find in North America has quite reached this, but there have been some solid nuggets that represented pretty good fortunes. The largest and finest nugget was unearthed in California on November 18, 1854, at Camp Corona, in Tuolumne county. It was found by Oliver Martin, and in the history of gold mining in that State it is known as the Oliver Martin Chunk. Pictures and bronze fac-similes of this wonderful piece of gold have been deposited in many mineral collections in the museums of Europe and America. The precious chunk weighed 151 pounds and six ounces, and was larger round than a man s body. It was almost all pure gold, mixed with some white quartz. When it was converted into bullion, after it had been on exhibition for a long time, the gold in it sold for $36,270 (£7,254). The nugget was found at the base of a tree where the lucky miner was digging a hole to bury his dead companion. The two had been prospecting over the hills and mines for weeks until nearly dead from exhaustion. Flower, Martin's companion, was killed by the storm which lasted several days and nights, and while more dead than alive the surviving miner tried to give him a decent burial. He was rewarded for his labour by discovering the largest nugget of gold ever taken out of an American mine. The lump was too large for him to dig out alone in his weakened condition, and he had to seek the assistance of other miners.

The next largest nugget was taken from the Monumental claim near Sierra Buttes, in Sierra County, California. It was found in August, 1869, by five miners who were working the claim as partners—W. A. Farish, A. Wood, J. Winstead, F. N. L. Clevering, and Harry Warner. They had been working their claim for some time when the fortunate discovery was made. The nugget was turned up accidentally, and upon examination it was found to weigh 1,593 ounces troy. They took it to San Francisco, where it was placed on exhibition for some months. The miners received for it $21,636.52; but this sum did not represent the amount of pure gold in it. The purchaser paid more than the gold was actually worth because of its advertising value in his store window. When finally melted $17,654.94 or about £3,530 were reaised for the gold.

Almost as valuable as this nugget was another found in June, 1866, at the old Ruby Belle claim north of Plumas, California. It was discovered by a man named Daniel Hill—a miner who probably is fairly typical of the men who hunted for gold on the Pacific coast in the fifties and sixties. Not only was he a typical character, but his life was as full of the ups and downs that generally follow one engaged in the pursuit of mythical gold fortunes. Twice in his life he found two large nuggets of gold that brought him in small fortunes; but he spent the money and finally died of delirium tremens in jail. He prospected all over the Western mining fields of the United States with the poorest sort of luck, except on these two distinct occasions when he found the big nuggets. The first one he sold for $17,000 (£3,400) in cash, although the actual valuə was said to have been more; but Hill had been down on his luck so long, and he was in such need of ready money, that he let it go to the first fair purchaser. The exact weight of the nugget has never been reported, and as it has long since been melted up, and the gold distributed to the four quarters of the globe, the actual size and weight will ever remain a secret.

Hill's second lucky find was made about five years later, in the fall of 1871. It was while placer mining in the old Dutch Flats that he washed out a nugget larger than a cocoanut. The nugget was almost all gold, and so pure that it sold for $14,000 (£2,800). The old miner quit working at once, and proceeded to spend his money in drink and gambling. In less than two years he was working in the mines again without a dollar to his name, anxiously and ex-

pectantly hoping to strike another big nugget; but fortune rarely smiles the third time upon the same individual, and he died without mkaing another rich find of any kind.

In 1870 there was a remarkable nugget or mass of gold found in the Rainbow mine at Allegheny. The miners who took out this lump gave out very little information concerning it, but shipped it immediately to London. Whether it was at once melted down there or not is a mystery. All that is known about it is that it was taken from the Rainbow mine, and sold for $23,000 (£4,600) in London. This price indicates that it must have been a nugget of remarkable size, and probably the second largest one ever found in the United States.

These are the prize nuggets of gold found in America, and they show distinctly how lavish Nature can be at times in distributing her wealth around in the bowels of mother earth; but there are many lumps of gold of lesser note that have been discovered at various times in the States, which one might well consider himself fortunate in picking up. Like most of the large nuggets these smaller ones have hailed chiefly from California, and they were found sometime between the fifties and sixties. Since 1870 very few nuggets of any special size have been discovered in the United States. The whole country has been pretty well prospected over for gold, and few corners of it exist where the placer miners have not been at work examining the rocks and soils at some time.

But exceptions to this can be cited. Less than a year ago a consumptive picked up a nugget not far from San Diego, Cal., valued at $1,400 (£280); but this had been washed out by a heavy mountain torrent, and no other traces of gold could be found in the neighbourhood. In 1889 two men found a huge lump of gold not far from Caliente, Cal., for which they received $2,750 (£550). It weighed 216 ounces, and the announcement of its discovery started gold miners to the scene by the scores. The finders were poor tramps who had been put off the westward bound train for not having money to pay their fares. There is something picturesque and romantic about a country where a wanderer can pick up a rock when penniless, and carry it to civilisation and receive a good year's income for it; but any one who is foolish enough to believe that such plums lie scattered about to any great extent should be undeceived. Nearly all of the nuggets have been found by accident, and old miners who have made systematic and continued search for them have failed to realise anything. Finding a nugget of gold is like drawing a big prize in a lottery—it comes only to one in many thousand, and then only once in a lifetime.

When we search the historical literature of the fifties and sixties we find that California was very fruitful in yielding nuggets of gold to those engaged in mining or prospecting. In 1855 a mass of gold and quartz was mined at French Ravine which sold for $10,000 (£2000). In this same Ravine other valuable finds had been made previously. In 1850 a rock, composed of quartz and gold, weighing 263 ounces was dug out of the sand, and brought for its lucky owner $4,893 (£978), and in 1851, about one year ater, a still more valuable lump was found. When melted down about $8,000 (£1600) worth of gold were obtained from the mass.

A ragged mass of rock and gold was discovered at Columbus, in Eldorado County, in 1853, weighing 360 ounces, and worth $5,625 (£1,125). In the same county, a few miles from the scene of this discovery, a nugget weighing 380 ounces was picked up and sold for $6,500 (£1,300). A third nugget worth $5,000 (£1,000) was found at Spring Gulch, also in Eldorado county, and the Frenchman who discovered it was unable to stand the good news and went insane; but the fortune he had been looking for was sent to his family, where it is to be hoped it did some good. Near Magalia, in Butte county, a nugget was found in 1859 that weighed fifty-four pounds, and

was valued at $10,690. Another near Columbia weighed fifty pounds, and contained $8,500 worth of gold. That the weight of the original nugget does not always determine its value is shown by another discovery on Sullivan's Creek, in 1849, near the scene of the last. It weighed only twenty-eight pounds; but the gold in it sold for $7,168 (1,433.)

Outside of California the nuggets of gold have never been extremely large, although the States have produced a great deal of the precious yellow metal, and are noted for the richness of their mines. Colorado, for instance, never produced a large gold nugget. The most valuable one ever mined in that State weighed thirteen pounds, and had considerable quartz mixed with it. North Carolina produced a freak once in the shape of an 80-pound nugget, but as it was not all pure gold it did not bring the big price one might expect.

It is generallly supposed that South America produced immense nuggets of gold, and that the ancient Peruvians and Aztecs gathered much of their immense store of it in this shape. The recent discovery of a $5,000 (£1,000) nugget in Patagonia has recalled the scientificconclusions of men interested in mining,and it has had the effect of inducing a stream of miners to migrate toward the southern half of the Western continent almost simultaneously with the exodus from the States to the Klondike andAlaska.

But in spite of the boasted riches of the California gold mines back in the fifties, Australia can show even a better record in the production of gold nuggets. The wonderful masses of gold that have been taken from her mines have won for them international names, and they have passed in history with the peculiar appellations that the rough miners gave to them. For instance the "Welcome Stranger" nugget is almost as well known as the "Kohinoor." It was found at Dunolly, Victoria, in 1869, and had a gross weight of 2,280 ounces. Fifteen years before this, a nugget had been found at Ballarat, Victoria, the gross weight of which was a trifle over 2,217 ounces. This lump was named "Welcome," and as it had monopolised this name by right of seniority, there was nothing to do except to increase the name for the larger nugget, and call it "Welcome Stranger."

Next to these two enormous nuggets of gold—the largest ever produced, except one—come the "Blanche Barkly," discovered at Kingower, Victoria, in 1857, and weighing 1,743 ounces, and the "Precious," taken from the Berlin Diggings, Victoria, in 1871, and weighing 1,621 ounces. A nugget taken from a mine at Ballarat, Victoria, in 1853, weighed 1,619 ounces; one from Burrandon, New South Wales, weighed 1,286, and another from Bathurst weighed 1,272 ounces.

"Lady Hotham," found in 1854, at Ballarat, weighed in the rough stage, 1,177 ounces. The "Viscount Canterbury," and the "Viscountess Canterbury," were two enormous nuggets taken from the Berlin Diggings, in Victoria, in 1870. The former weighed 1,105 ounces, and the latter 884. The "Kum Tow" nugget was also taken from the Berlin Diggings, in 1871, and weighed 718 ounces. Finally a mass of gold and quartz was taken from the Ural Mountains, at Miask, in 1842, which weighed 1,158 ounces gross.

If one could pick up a few stones of this size nugget mining would be very profitable business, and placer gold miners would soon abandon their form of work; but there is no more uncertain occupation in the world than hunting for gold nuggets. Even the romantic and imaginative miner never places much faith in finding nuggets, for he knows that they are few and far between. Still the very existence of these massive lumps of gold—fortunes rolled up in little heaps—give spice and attraction to gold mining that buoys up flagging and discouraged spirits many times, and lures the miner on from one hope and disappointment to another, until death terminates his career, or a lucky find places him beyond want for the rest of his natural life.

THE MAGNETIC CONCENTRATION OF ORES.

By Professor William A. Anthony.

FROM a very early date it has been known that certain ores of iron possessed magnetic properties, and that still other minerals, not themselves magnetic, were attractable by the magnet. The number of these that were susceptible to the attraction of the comparatively feeble permanent magnets was very small. But the discovery of the electro-magnet furnished a means of bringing substances under the influence of a most intense magnetic field, with the result that all substances were, to a greater or less extent, found to be susceptible to magnetic influence.

The vast majority of these, however, are diamagnetic, and are not at all attracted by the magnet. A comparatively few are feebly attracted, and a very small number are attracted by a force more than one one-thousandth of that exhibited by iron.

Among minerals, magnetite, or magnetic oxide of iron, and pyrrhotite, or magnetic sulphide of iron, are almost the only ones whose magnetic properties are readily recognised, although a considerable number of other minerals are feebly attracted, but with forces so small that it is only by means of delicate instruments, and by the use of extremely powerful electro-magnets that their existence can be demonstrated.

From an early date the idea has been entertained of separating magnetic from non-magnetic substances by the use of the magnet, but up to a very recent date it had hardly been thought of to do more than separate iron from other substances, or magnetite and perhaps pyrrhotite from other ores. The magnet has been used for separating iron chips and turnings from the brass chips collected in shops where both metals are worked together. Special magnetic separators have been devised for the separation of iron from rags used for making paper, and for separating from paper pulp the finely divided iron that is ground up with the rags in the paper engine or that comes from the wear of the engines themselves.

Numerous magnetic separators have also been devised for separating magnetite from other ores or from other substances with which it is often found associated, and descriptions of such machines in which electro-magnets were used will be found among the patents granted nearly fifty years ago when the only sources of the electric current were the primary batteries then in use. With such sources the cost of the electric current was, however, too great to warrant a very extended use of magnetic separators, and until the invention of the dynamo machine reduced the cost of electrical energy, inventors and users of such separators generally had to content themselves with such results as could be obtained by the use of permanent steel magnets.

The advent of the dynamo machine, however, gave a new impetus to the design of magnetic separators, and from 1880 to the present time a great variety of such machines have been invented, making use of electro-magnets energised by means of currents from dynamo machines.

The ways in which the powerful magnetic fields thus placed at the command

of the inventor have been utilised to effect the separation of the magnetic from the non-magnetic materials, are various and often interesting from the ingenuity displayed.

But, however various the different forms, the general principle is always the same. The mixed materials are carried into a magnetic field where the magnetic portion is diverted from the course it would otherwise take, and is thus separated from the non-magnetic portion and carried away and deposited by itself.

A few magnetic separators have been constructed in which the magnet poles are placed in the passing stream of mixed materials. The magnetic particles are arrested by the magnets and gradually accumulate upon them. This accumulated material must then be removed from time to time; otherwise the magnets would become overloaded and would no longer perform their office.

Such a construction could not be used, except where the quantity of magnetic material is very small. Where considerable magnetic material is present the separator must be so constructed that it may be continuously removed. While such separators are all constructed upon the same underlying principle, as stated above, they may be roughly divided into two classes,—one in which the mixed material is carried around, or in front of, the poles of a magnet and in which the magnetic portion is deflected from its course sufficiently to be deposited in a receptacle by itself; and the other in which the material, spread out upon an apron or similar carrier, passes in front of a magnet which picks up the magnetic portion, which is then, by the movement of the magnet itself, or by means of a supplementary carrier, removed to the receptacles provided for it.

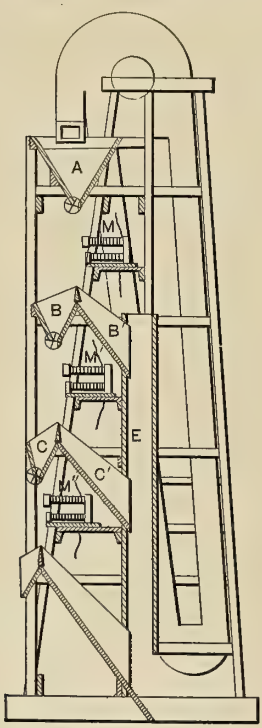


FIG. 1

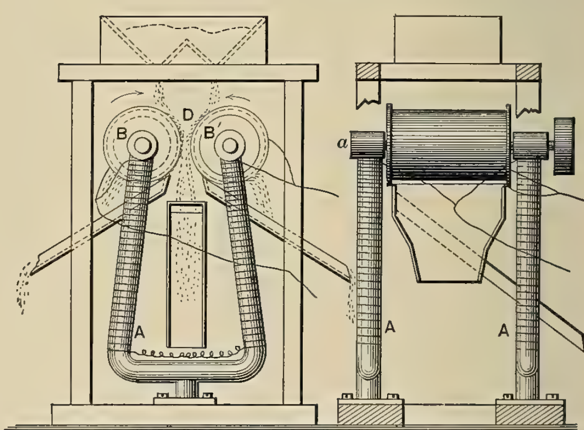


FIG. 2.

Separators of the first class have taken numerous forms. In Fig. 1 the material to be operated upon, in the form of coarse powder, having been passed through a sieve to separate all stones and lumps, is conveyed to the hopper *A*, from which it falls in a thin sheet in front of a magnet, *M*, which is so adjusted that it merely deflects from its course, but does not attract to itself, the most strongly magnetic material. This then falls into the shute *B'*, while the undeflected portion falls into the hopper, *B*, from which it drops, in a thin sheet,

n front of the magnet M'. The latter is so adjusted as to act upon magnetic material that is too weak to be drawn aside by the first magnet and so produces a further separation. The material which passes M' without devia-

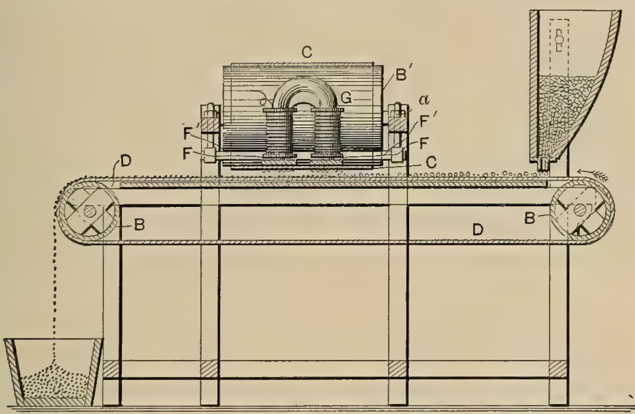


FIG. 3.

tion goes into the hopper C, and is then subjected to a further separation by the magnet M''.

More than one magnet is necessary in this apparatus, because if the first magnet were placed sufficiently near the falling sheet to take out all the magnetic material, the strongest of this would be apt to be drawn to the magnet and cling to its poles.

Fig. 2 shows two views of another form of separator of the first class. Here the two cylinders, B and B', are supposed to be rendered strongly magnetic by means of the horse shoe magnets marked AA. With such a construction the greatest magnetic strength would exist in the region between the two cylinders where they most nearly approach each other. From this point the magnetic strength would grow rapidly less as the cylindrical surfaces recede from each other, until a point would be reached where it was no longer sufficient to retain the magnetic material which would then be deposited as the figure shows:

Figs. 3, 4, and 5 represent a separator of the second class. The magnets G, having plates F to serve as poles, are supported above an apron, D, upon which the mixed material is spread in a thin sheet. As this apron passes beneath the magnet, the magnetic material is picked up and held against the under side of a transversely moving apron, C, until it is carried beyond the edge of the apron D.

Then, as it leaves the region of the magnetic action, it drops into a receptacle, as shown in Fig. 4. The non-magnetic material remains upon the apron D, until it passes over the pulley B, when it is deposited, as shown in Fig. 3.

In this form of separator the apron D, is often considerably lengthened and three or four magnets and transverse aprons follow one another over it, each succeeding magnet being placed a little nearer to the apron D, than the one that precedes it. In this way magnetic material that has escaped the first magnet may

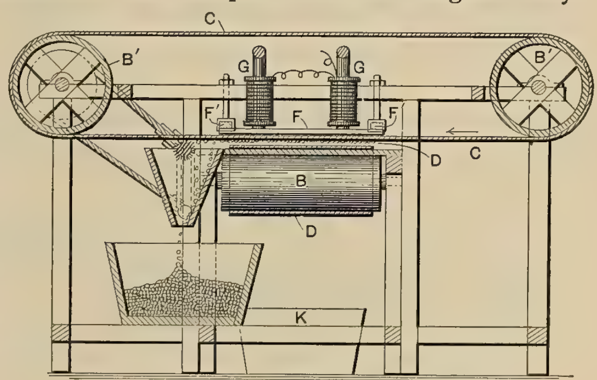


FIG. 4.

be picked up by the second, and so on.

Numerous other forms of the second class might be adduced, but it is not the purpose here to describe all the forms that the magnetic separator has taken,

but rather to illustrate a few of the typical forms.

As already stated, until a very recent date separators have been designed with reference to the removal from a mixture, of substances that are quite strongly attracted by the magnet. Indeed, it had not been recognised until very recently that the feebly attracted minerals were amenable to magnetic separation at all. The magnets represented in the separators so far described would not at all answer the purpose of removing these very feebly attracted substances. Why attempts were not made earlier to act upon the feebly magnetic minerals will be understood when it is remembered that there are two distinct classes of substances attractable by the magnet with a very wide gap between. Taking the attractability of iron at 100,000, that of magnetite is about 65,000, while the feebly attracted minerals run from 40 to 150, forces which, compared to that of magnetite, are infinitesimal. Of all minerals pyrrhotite only is comparable to magnetite in magnetic strength, and even it is much weaker than magnetite.

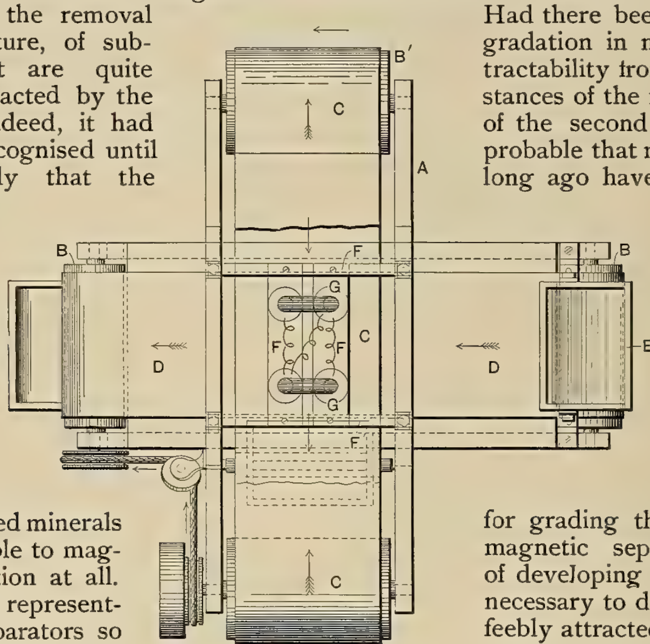


FIG. 5.

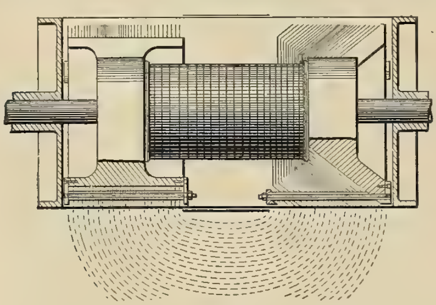


FIG. 6.

Had there been a regular gradation in magnetic attractability from the substances of the first to those of the second class, it is probable that means would long ago have been found for grading the action of magnetic separators and of developing the strength necessary to deal with the feebly attracted minerals.

But in consequence of this very wide gap, unoccupied by substances having an intermediate attractability, practical engineers have not recognised the feebly attracted minerals as exhibiting any magnetic force at all. Or if they knew of the existence of these feeble attractions, it is no wonder that they did not consider them practically available for magnetic separation, when it is remembered that the magnets that successfully separated the recognised magnetic substances would have had to be increased in strength from 500 to 1500 times in order to deal with the minerals of the other class.

Some inventors, in order to separate the more feebly magnetic ores of iron, have proposed to convert these ores into magnetite by roasting. But this process, although successful with certain ores, is not always applicable, and, moreover, is costly.

Such a process was employed for separating the iron-bearing minerals from the zinc ores of the Franklin

mines, of New Jersey, and was, to a degree, successful; but the expense of the process led Mr. J. P. Wetherill, of the Lehigh Zinc and Iron Company, of South Bethlehem, Pa., to institute a series of experiments looking to the direct magnetic concentration of these ores without the preliminary roasting.

To understand the difficulties and discouragements that beset the experimenter, it must be understood that none of the constituents of the ore of the Franklin mines had ever been recognised as attractable by the magnet. The ore is known as franklinite ore, and is an aggregation of several minerals,—franklinite, a mineral containing zinc, iron, and manganese; willemite, a silicate of zinc; zincite, an oxide of zinc, together with calcite, garnet, and a number of others. The principal object is to obtain the willemite and zincite free from the franklinite, as the presence of the latter is a fatal obstacle to the reduction of these zinc ores in the Belgian furnaces.

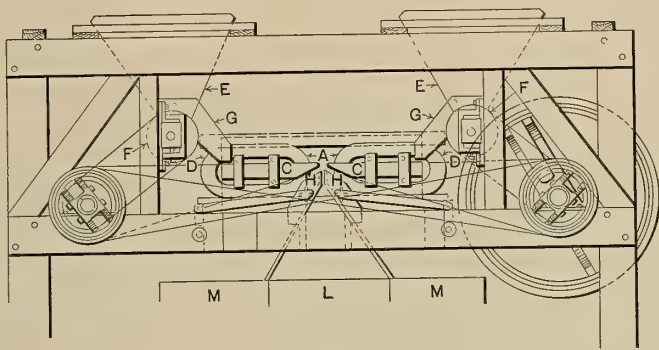


FIG. 7.

The fact that the franklinite could, by roasting, be rendered sufficiently susceptible to magnetic attraction to be removed by the separators then in use, suggested that it might be somewhat magnetic in its natural condition. But tested in the ordinary way, it showed no evidence of magnetic susceptibility, and it was only after repeated trials by the strongest hand magnets that Mr.

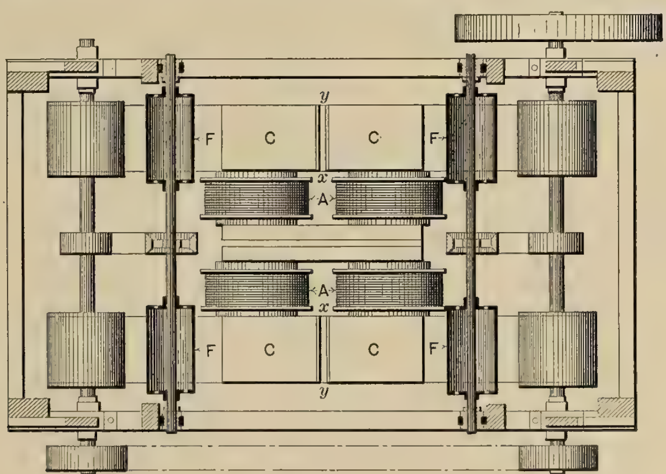


FIG. 8.

THE HEAD FRAME OVER THE MINE SHAFT AT FRANKLIN FURNACE, N. J.

Wetherill found that, now and then, a fine grain of franklinite could be lifted out of a mass of powder. This was, however, sufficient to demonstrate the attractability of the mineral, and the problem now was to obtain the magnetic strength required for its separation on a commercial scale.

No assistance toward the solution of this problem was furnished by the then existing magnetic separators. On none of these would any amount of current in the magnet windings give a magnetic strength that would produce any impression whatever upon the franklinite ore. It was evident that for obtaining a very intense magnetic field the design of the magnets in existing separators was radically wrong.

The principles that underlie the construction of electro-magnets may be stated in a few words. A coil of wire carrying a current possesses a power to develop magnetic force which is measured by the product of the number of turns in the coil and the strength of current flowing in it. This product represents "ampère-turns," and is a measure of the "magneto-motive force" of the coil. Such a coil develops a magnetic force which is assumed to be represented by "lines of force" forming closed curves, linked into the coil. As a further assumption a line of force is taken to represent a unit of magnetic force, so that the number of lines through a given coil represents the total magnetic effect of that coil, and the number of lines passing through unit area at any point, represents the strength of the magnetic field at that point.

The total number of lines developed by any coil is the quotient of the magneto-motive force of the coil and the *reluctance* of the magnetic circuit. This reluctance is a quantity akin to resistance in an electrical circuit, and may be considered as representing the opposition offered by the material filling the space occupied by the lines, to having lines of force set up in them. The reluctance of air is high, and of iron, when far from saturation, very low.

An electro-magnet consists of a coil of wire surrounding an iron core usually having a horse-shoe form. The magnetic effects are exhibited in the air gap separating the ends of the horse-shoe. In order that these effects may be in-

tense, it is necessary that the number of lines per unit area in the air gap should be large.

To obtain a large number of lines requires great magneto-motive force and small reluctance. To obtain small reluctance requires a large mass of iron far from saturation by the magnetic lines developed. But to obtain intense effects requires a large number of lines per unit area of air gap. Hence, the area of air gap must be small.

It can now be understood why the early magnetic separators failed to produce a field of such intensity as to act upon the feebly magnetic substances. Referring to Fig 2, the iron cores of the magnetising coils are long and of small area; hence they have a high reluctance. The air gap area is a rectangle whose length and width are at least equal to the length and diameter of the polar cylinders. This area is, therefore, many times the cross section of the magnet cores, and the lines of force which would saturate the cores would be thinly distributed over this air gap.

So with the magnets of Figs. 3, 4, and 5. There are two magnet cores having for common pole pieces the long flat plates, *F*. The effective magnetic field, as shown in Fig. 3, has an area equal to the entire under surface of these plates, which is many times the area of the cross section of the magnet cores.

Even if the two magnets were as close together as possible, and the plates as short as such a disposition would admit, their area would still be many times that of the cross section of the cores, and all the lines that could possibly pass through the cores would be but thinly distributed when scattered over the surface of the plates.

These examples show not only no attempt to concentrate the lines of force and so produce intense magnetic effects, but it would seem from them that the purpose of the inventors was rather to distribute the force over as large as possible a region.

Fig. 6, from a patent appearing as late as 1893, shows this plainly. Here the inventor makes his pole pieces of thin sheet iron, set edgewise and spaced at unequal distances with the avowed purpose of obtaining an even distribution of the lines of force over the entire area. Here, again, the air gap area is many times larger than the cross section of the magnet core.

Now in order to produce that intense magnetic field that is needed to operate upon the magnetic materials of the second class, the course pursued must be the exact opposite of that which the figures referred to exemplify. Instead of small magnet cores and large air gap area there should be large magnet cores and small air gap area—large magnet cores to reduce the reluctance and permit of the production of a large number of magnetic lines, and a small air gap area through which all these lines must pass, and in which, therefore, they are crowded together, which is the same thing as saying that the magnetic force is intensified.

It was left for Mr. Wetherill to fully appreciate these principles of magnet construction and to apply them in practical form to the construction of magnetic separators. Figs. 7 and 8 show one of the forms which the Wetherill separator has taken. The pole pieces *C*, are shown to be beveled to a thin,

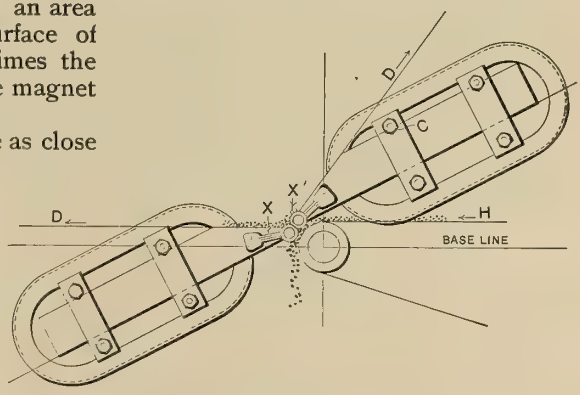


FIG. 9.

THE CRUSHER AND CONCENTRATOR BUILDING AT FRANKLIN FURNACE.

rounded edge, and brought near together. The working air gap is the narrow space between these polar edges, and is, therefore, very short and of small area, the latter being practically represented by a rectangle whose length is $x\,y$, as seen in the horizontal section, and whose width is the thickness of the edges of the pole pieces, as seen at A in the side elevation.

Through this very small area pass nearly all the lines of force developed by the large magnet coils through the heavy magnet cores and yokes which form the rest of the magnetic circuit, and present a very small magnetic reluctance. It will be noted that the air gap area is here much smaller than the cross section of the magnet cores, instead of being many times larger, as in the earlier separators; and from this results the enormous concentration of magnetic force.

Into and through this intense magnetic field the ore to be acted upon is passed. But all this will be better understood if the complete operation of the apparatus is described. The mixed materials in coarse powder, sized by passing over suitable screens, is brought through troughs, E, Fig. 7, which is taken from a machine regularly installed for operation, to the rollers F. By these rollers the material is fed through the troughs G, in a thin layer upon the belts D. These travel toward the gap and pass by friction around the rounded edge and along the beveled lower face of the pole pieces, as shown. The material on the belts, therefore, passes directly through the gap at A, almost in contact with the rounded edge of the pole pieces, where the magnetic force is most intense.

Material that is absolutely non-magnetic drops vertically from the pole pieces between the shutters HH', into the receptacle L. Material that is at all attracted is carried by the belt partly under the rounded edge, and, if sufficiently susceptible, may even be carried on to the beveled under surface of the pole pieces; but it will sooner or later reach a point where the magnetic force is too weak to hold it, and it will then drop off. It will, therefore, be seen that by properly adjusting the shutters HH', this magnetic material may be guided into the receptacles MM.

The pole pieces in these machines are adjustable, and the air gap A, may be made wider or narrower, thus varying the magnetic intensity. This intensity may also be varied by varying the cur-

rent in the magnetising coils. By these means the apparatus may be adapted to the separation of materials varying greatly in magnetic permeability. Indeed, a series of these machines may be so adjusted as to separate from a mixture of materials of varying permeability, first that of the highest, second, that of the next highest, and so on until the different materials are all separated and classified in the order of their attractability.

The machine above described is best adapted for dealing with materials in the form of coarse powder. For operating upon material in fine powder a somewhat different arrangement of the magnets is found necessary. Such an arrangement is shown in Fig. 9.

The magnet poles are here inclined, with their beveled faces upward. The finely divided material is brought by the belt H into close proximity to the air gap where the magnetic material is, as it were, picked up, most of it going to the rounded edge of the left-hand pole-piece, when it is carried by the belt D, moving in the direction of the arrow, upward through the gap and to the left over the pulley around which the belt passes.

Some of the material may go to the right-hand pole-piece and be carried by its belt a short distance up the steep incline, as shown at X'; but the magnetic force very rapidly becomes weak as the distance from the edge increases, and this material soon falls back, down the incline, and finally falls over on to the left horizontal belt and is carried away to its proper receptacle.

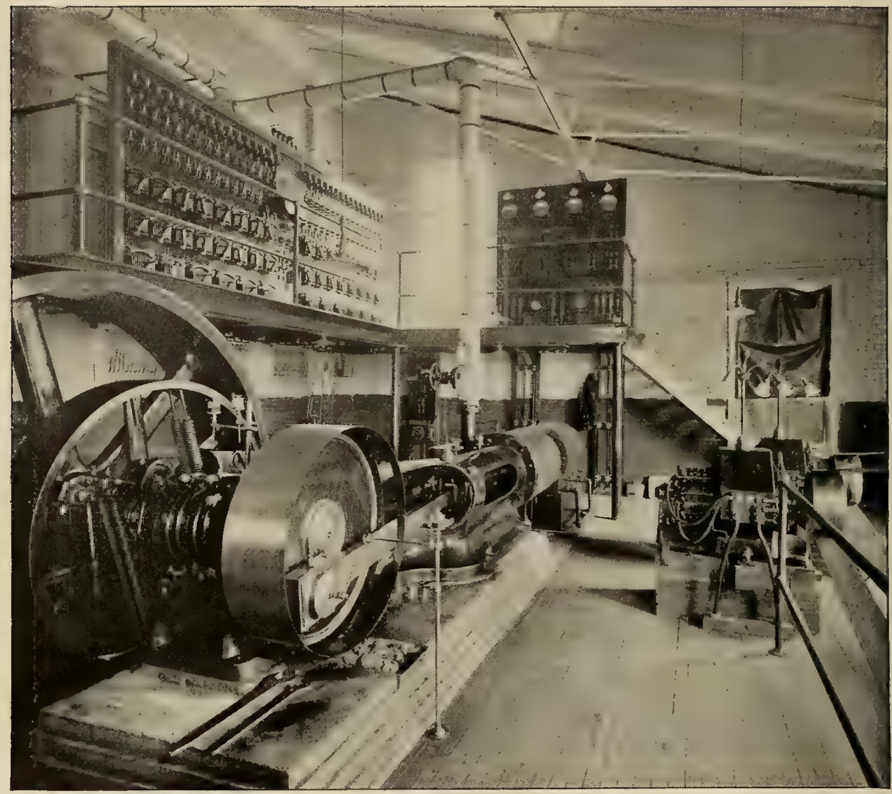
It will be seen that the separators represented in Figs. 7 and 8 are separators of the first class, in which the material is carried into a magnetic field by which the magnetic portion is deflected from the course it would otherwise follow; while the separator of Fig. 9 is of the second class, in which the magnetic material is lifted out of the mixture and is then carried away by a supplementary carrier.

As has been said, it was the necessity for separating the iron and manganese-bearing minerals from the pure zinc-bearing minerals of the franklinite ore that led to the development of these powerful magnetic separators; but it was soon found that the extraordinary magnetic power that could be achieved by properly designing magnets along the lines pointed out, was sufficient to permit the separation of substances far less susceptible than even franklinite. Hematite, siderite, garnet, pyrolusite and others could be separated from deleterious substances, or from ores in which they are themselves objectionable ingredients. Manufactured salts of iron, manganese and chromium are affected by these machines.

A SIDE VIEW OF ONE OF THE MAGNETIC SEPARATORS.

These Wetherill separators are in operation at the Sterling Iron and Zinc Company's mines, at Franklin Furnace, New Jersey, in a plant capable of handling 300 tons of ore per day. The photographic views accompanying this article illustrate various features of this plant.

The illustration on page 438 shows the head frame over the mine shaft, and, at the far right, the building in



A VIEW IN THE ENGINE-ROOM, SHOWING SWITCHBOARDS AND DYNAMOS.

which the crushing and concentrating operations are carried on. The shaft is about 1000 feet deep. From the bottom run the working entries where the ore is mined. On one side of the shaft, at a depth of 600 feet, is a pumping station, to which all the water that enters the shaft at a higher level is led. A smaller pumping station at the bottom of the mine raises the water from the bottom to the main station, from which all the water is pumped to the surface.

The mining operations are carried on by rock drills operated by compressed air, the air so used being sufficient for the ventilation of the mine. The latter is lighted entirely by incandescent lamps, and is, on the whole, a very different place from what one would imagine a mine to be, especially if his ideas had been derived from visits to the black and dirty and gas-producing mines of the coal regions.

The ore brought up from the mine is carried in cars up the inclined track to the top of the building at the far left. There it passes into the stone breakers and from them to the crushers and screens for sorting the different sizes.

From its entry into the building until it is finally separated into its constituent parts and ready to be stored for shipment, the ore follows its prescribed course by the action of automatic elevators and carriers, and is never touched or handled by manual labour.

The illustration on page 440 is a nearer view of the building where the crushing and concentrating are carried on. The railway for bringing in the ore is here more plainly seen. The ore, in the various operations, passes through the entire building, from top to bottom, and from left to right, and is finally delivered at the far end beyond the brick building, which is the engine house.

Within the separator room the unsized ore from the crushers goes first to roughing separators by which some of the franklinite is removed. The remainder then goes to the sizing screens, where it is separated into five sizes by screens of 10, 16, 24, 30, and 50 meshes to the inch.

Each size goes to a tank provided for it. From each tank the product goes to a separator appropriately adjusted for material of that size, the finest going to a series of inclined magnet machines like that shown in Fig. 9.

Each of the machines consists of three magnet separators. The sized product from the tank is delivered to the left-hand one, and that which escapes the magnet goes to an elevator, by which it is delivered to the second machine, where again the part that escapes the magnet goes to another elevator by which it is delivered to the third separator, which is supposed to effect the final and complete removal of all magnetic material.

The several magnetic minerals, consisting of franklinite, garnet, tephroite, and fowlerite, which are removed from the mixed ore by the several separators in this plant, are all carried by suitable carriers to a common point and are finally delivered outside the building. This material serves for the manufacture of zinc oxide and spiegeleisen.

The non-magnetic material delivered from the third separator of each group, which consists of willemite, zincite, and calcite, is carried to jigs where the calcite is removed by the usual process of jigging. The fine zinc ore from the inclined magnetic machines is not jigged, but goes into the general product with the calcite which it contains. The finished product of zinc ore is then dried and packed in sacks for foreign shipment, or loaded in bulk for shipment to American zinc works.

The illustration on the opposite page is a view of one end of the engine room, showing the switchboards and dynamos. The small switchboard contains the switches and instruments pertaining to the electric lighting circuits. The large switchboard on the left is used exclusively for the magnetic separation circuits. The rheostats, shown in three rows on the lower half of the board, serve for regulating the currents in the several separator magnets. The switches above the rheostats are used to cut an ammeter into any one of the circuits, so that the current upon it may be observed.

Besides these there are instruments for automatically indicating any failure in a circuit, and an annunciator call.

A small engine and dynamo on one side of the engine room, which does not appear in the illustration, is run continuously for supplying light in the mines when the main engines are stopped.

The power consumed by the magnets of these separators is small, being only about 100 watts to each magnet, and, since the ore is handled entirely by mechanical carriers from the time it is brought in from the mine until it is ready for shipment, the item of labour is reduced to a minimum. The process yields the zinc ores practically free from admixture with deleterious minerals and at a very great saving of expense as compared with the former process involving the preliminary roasting.

THE CENTRAL OPERATION OF DISTANT DEVICES

On Shipboard or Elsewhere.

By W. B. Cowles.

THE manipulation and control of distant mechanical devices by central station methods is destined to become a matter of great economic importance in most of the industries; it is already a matter of vital necessity to the safety of life and property on land and sea. This field of engineering is new; the only material step taken in it so far is the perfecting of switch and signal systems on railways.

A broader and more advanced position for general purposes is now taken up by what the writer would call the "Long-Arm" system, inasmuch as it enables an operator in his central station to reach out with any desired power and virtually place his hand on a distant device, manipulating, adjusting and locking it in any part of its movement at will with that precision of control and full knowledge attainable only by a continuous telltale and signal equivalent to the touch, the eye, and the ear combined.

Given such a system, its use in the arts is not small; it is involved, for instance, in the comprehensive operation of valves and gates in connection with pipe lines, tanks, reservoirs, canals, sewage plants or electric water-powers; and in the safe and systematic control of doors, hatches and valves for localising disaster from fire, flooding or gas in ships, mines, tunnels and buildings. It may, therefore, be of general interest to know something about this system and one of its recent practical applications for the operation of water-tight bulkhead doors on the United States cruiser *Chicago*.

The system is hydraulic. For many practical reasons a suitable mixture of pure water and glycerine or calcic chloride seems to be the best medium to use in small pipes for causing and registering motion at considerable distances. There are two general schemes embodied in the system for connecting the distant device with the central station, namely, the "double or individual line," and the "single or common line" of piping, the scheme which adapts itself best to the needs and conditions of any particular case being used for that case.

In the double line arrangement each distant device is connected to, and represented in, the central station by a primary circuit. This circuit consists of a power cylinder and a telltale cylinder of equal piston displacements, the former at the device, with its piston rod connected to it, and the latter at the central station with its rod graduated or moving over an adjustable scale. A controlling valve (a six-ported cock, or equivalent poppet valves) is placed on, or near, the telltale. The two cylinders and the valve are suitably connected by a double line of small pipe, usually $\frac{1}{8}''$ to $\frac{3}{8}''$ standard size, capable of being bent and run in any direction such as an electric cable will take, but being perfectly harmless and requiring no protection. Similar pipes also connect the valve to the pressure and exhaust mains.

The primary circuit, being full of liquid throughout, is so arranged that when the lever of the controlling valve is thrown, say, to the right, liquid flows from the pressure main through the

valve toward the power cylinder in one pipe of the double line, moving the power piston and distant device in a certain direction. This also causes the power piston to push liquid in the other pipe of the double line toward the valve and through it to one end of the telltale, forcing its piston to move synchronously with the distant device (the liquid being practically incompressible), and at the same time push liquid from the other end of the telltale through the valve toward the exhaust tank. Throwing the controlling lever the other way reverses the movement, intermediate positions regulate the speed, and the mid-position locks the whole circuit.

The primary circuit as above described gives absolute, continuous and precise knowledge of movement in the distant device by both eye and touch. If it is in any case desired to add the ear as well, it may be done by suitably attaching a small bell or clicker to both power cylinder and telltale rods, and arranging these to sound at any desired interval of movement or continuously during the whole movement.

The central station consists of any convenient combination of the desired number of telltales and controlling valves, together with a small accumulator and pressure pump and two small tanks, one for the exhaust, under a back pressure, and one for a reservoir and suction box to the pump. The telltales and valves are grouped on a board or boards and are numbered or labelled in such a way that almost any desired number of distant devices can be operated, controlled, inspected, locked and reported by one responsible operator, and by arranging operators in watches, as at sea, a continuous supervision and control may be maintained. The back pressure on the exhaust allows signalling or the use of a "liberty valve," referred to later, on any primary circuit, and keeps the whole system full of liquid,—an important thing for the accuracy of the telltales. With a limited number of primary circuits a small hand pump may be used for pressure.

An emergency circuit is used with a central station wherever there are distant devices which need to be operated quickly and all together to insure safety, as in the case of doors and hatches in a ship, a mine, a tunnel or a building when danger from fire or flood threatens. The emergency circuit is simply a primary circuit having its controlling valve and telltale placed at a point where the danger to be guarded against can first be discovered, as on the bridge of a ship or in the main shaft of a mine. The power cylinder is placed in the central station, with its piston rod so connected as to simultaneously throw into the safety position any desired number of controlling valve levers. This is done by a connecting bar or rod working emergency levers which are fitted under the hand levers of the controlling valves in such a manner that when the emergency circuit is in its normal position all valves are free to be worked by the hand of the operator, but when this circuit is used, the emergency levers throw their valves to operate for safety and lock them there beyond the control of the operator.

This emergency action may also ring a special alarm gong, and it then becomes the immediate duty of the operator to see by his telltales that all distant devices connected with the emergency circuit are moving to their safe positions properly. Any failure to do this may be quickly detected and located by the operator, and prompt steps may be taken to clear a certain device without wasting time in general inspection; and even where a certain device cannot be cleared from some possible obstruction it is of immense importance in cases of fire, gas or flooding to know just where the fault is and so be able to localise the danger.

An emergency circuit may have two or more telltales and controlling valves with a single power cylinder at the central station, so that it may be "thrown" from any one of two or more points, thus more completely covering the need of prompt discovery and insuring prompt action in case of threatened danger.

Referring to the "liberty valve," already mentioned, it should be borne in mind that any system for the central

control ot distant devices involves a careful consideration of the effect of such a system upon the attendants or crew, and the consequent counter effect upon the system itself. If such a system entirely cuts out and throws away the valuable human discretion and judgment now lodged with the attendants at a device, it is defective. If such a system can imprison the attendants or injure them by excessive rapidity of movement in the device, it is dangerous.

For instance, if doors or hatches on ships or in mines are arranged to be shut and locked by even regulated movement from a central station, and if men must, in addition to the many chances of death now hanging over them, face the additional chance or choice of being guillotined, or imprisoned for slow drowning, suffocation or roasting, as the case may be, then such a system is inhuman.

Further, any such system could not remain long at work anywhere; the attendants would shore or jamb the doors and hatches immovable in some safe position for themselves, and take their chances in an emergency, in spite of all the regulations and discipline imaginable.

To avoid all this the "Long-Arm" system involves a liberty valve in every primary circuit where it is desirable to leave opportunity of control in the hands of attendants at the device, and it is perfectly feasible to regulate and limit the uses of this liberty valve by instructions and orders, because with it the system has none of those features which bring out combativeness toward it on the part of attendants. The liberty valve and the relief from manual labour in handling heavy doors and hatches win the co-operation of the attendants.

The liberty valve is a simple, three-way cock (or equivalent poppet valves), placed conveniently near the device in, say, the closing pipe of a power cylinder, and fitted with springs on the handle, so that it may be turned to a stop and fly back to its normal position. The straight-way passage in the valve is normally a continuation of the closing pipe, but when the valve is turned 90 degrees (this can be done at any time and in an instant) the part of pipe leading from the controlling valve is blanked off and the other part leading to the power cylinder is connected with the atmosphere, thus allowing the exhaust back pressure to open the device, assisted by hand when desired, the telltale showing the whole story meanwhile. The exhaust port of the liberty valve connects with a pipe discharging above the power cylinder so as not to drain the latter. This preserves the hydraulic adjustment in the circuit.

A small port connecting two passages in the controlling valve, and closed by a spindle central in the main valve stem, is used for filling the primary circuit, and for periodic inspection and checking of the adjustment. Telltale cylinders, when very large, may be replaced by a suitable liquid meter to save space in the central station.

Maintenance of the system is very simple, as no part is subject to much wear; it is far superior to any possible electric system in this respect and in consequent reliability. Periodic inspection and checking of adjustments for the very slight leakage possible, maintain the system in constant readiness, and whether actually moving one or more distant devices, or in a state of rest, the "double line" is a constant watch dog.

In the "single line" the power cylinder at each distant device is connected by a suitable branch pipe to a pressure main running from the accumulator, and the exhaust or return is similarly brought back, by a run of pipe and branches in common, to the suction box or reservoir of the pressure pump, just as in a hydraulic plant for tools and lifts in a factory.

The central station in this case is simply the location of the accumulator and pump with its reservoir, regulating valves and emergency attachment; there are neither telltales, controlling valves nor operator. The emergency circuit is identical with that described for the double line, but the scheme of emergency operation is entirely different. Preferably, a steam accumulator and

pump, of any reliable type, are used. The steam is admitted through two reduction valves "in series" and set, say, to pass 100 pounds and 50 pounds pressure, respectively. A bye-pass pipe connects between the two reduction valves and contains the emergency valve controlled by the power cylinder of the emergency circuit. In its normal condition the emergency valve is closed and the steam pressure is maintained at, say, 50 pounds on the accumulator and pump, constantly maintaining the required hydraulic working pressure on the whole system. When the emergency valve is opened, however, the higher pressure of steam, say, 100 pounds, is immediately substituted for the lower and the hydraulic working pressure on the whole system is immediately doubled. This causes all the distant devices to move into the desired safe positions in a manner to be described.

A valve box for each distant device in the system is conveniently interposed between the pressure and exhaust branch pipes and the power cylinder and connected to the latter by an "opening" and a "closing" pipe. The central feature of this valve box is a four-ported operating-liberty cock (or equivalent poppet valves) with a spring handle holding it in its locked and normal position. Radiating from this valve are the several passages and connections:

1. From the pressure-branch pipe, fitted with a check valve and a side connection for a hand pump to be used at the device in case pressure is lost in the branch pipe from any cause.

2. To the "closing" pipe, with a bye-pass from the pressure-branch pipe in which is placed the first, adjustable, spring-relief valve, set to allow all pressure above the hydraulic working pressure (of, say, 150 pounds) to pass into the power cylinder, regardless of the operating-liberty valve.

3. To the "opening" pipe.

4. To the exhaust-branch pipe, with a bye-pass from the "opening" pipe in which is placed the second, adjustable, spring-relief valve, set to allow all pressure above the hydraulic working pressure to pass into the exhaust-branch regardless of the operating-liberty valve.

When a hand pump is used at the device, the exhaust is, preferably, made to pass through a reservoir in such a manner as to maintain a constant supply for the pump, equivalent to the volume of power cylinder.

The operation is now plain. Any power cylinder and its device may be moved, controlled, and locked in any position at will by an attendant using the operating-liberty valve and the hydraulic working pressure, the spring handles instantly returning the valve to its normal position and water-locking the device when the attendant removes his hand.

When the emergency circuit and valve is used to throw the increased pressure on the system the following takes place at every valve box:—

The emergency pressure passes through the first relief valve to the "closing" pipe, causing, say, 300 pounds per square inch on its end of the power piston; on the other side of this piston the back pressure cannot rise above 150 pounds per square inch owing to its release through the "opening" pipe by the second relief valve to the exhaust; this results in a net effective pressure of 150 pounds per square inch to close for safety.

When this safety closing endangers an attendant, it may be instantly stopped and reversed by the operating-liberty valve, which, when released, immediately allows the closing for safety to take place again.

From the foregoing it may be seen that among the many obvious applications of the "Long-Arm" system the operation of water-tight doors in bulkheads on board ship is an important one. On all first-class passenger-liners and on all large war-ships a great percentage of the total cost is spent directly and indirectly on bulkheads or on what these bulkheads necessitate. No passenger would willingly make a voyage on a liner which was not known to have a cellular structure, and no government

would think of building a battle-ship or cruiser without bulkheads. Yet it is a fact, well known at least to all seafaring men and shipbuilders, that these bulkheads, strong and perfect in themselves, are precisely as safe and efficient as the doors in them and not a whit more so.

The doors, as at present constructed and operated, are notoriously bad and dangerous. They have been the direct and known cause in the loss of many lives and many good ships, and are, doubtless, chargeable with many more ships on the list of "missing and unaccounted for." It is astonishing to the expert to see the general public, and even sea-faring men, so ready to accept the prevailing superstition about the safety of bulkheads. The best possible bulkheads without equally good doors, operated on a safe system, are about as good as a chain with a link missing. The history of marine disaster has taught us this if it has taught us anything, and yet we go on crossing the Atlantic in liners of much-vaunted safety and bragging about invulnerable battle-ships, apparently with implicit confidence in this bulkhead fetich.

There should be as few doors as possible, and some very able experts contend that there should be none. On the other hand, most captains and chief engineers say they must have doors. Manifestly the only way out of the difficulty is to get safe doors, safely operated. The number of water-tight doors and hatches on a first-class battle-ship is over 350, and there are nearly 300 valves and gates connected with ventilating, draining and flooding the hull and involving the safety of the ship. It will, therefore, be seen that the systematic control and operation of these devices is a matter of no mean importance.

It takes about 110 men to look after these details alone in response to a collision alarm under the present conditions, and it is a matter of very grave doubt on the part of those best informed as to whether the supreme efforts of these 110 men can attend to doors, hatches and valves quickly enough to save the ship.

It was an appreciation of all this that led the United States Navy Department to look carefully into the merits of the "Long-Arm" system and order a trial installation on the cruiser *Chicago* for operating water-tight doors in the engine and boiler rooms, including all coal bunker doors in the ship.

OCTAVE CHANUTE.

A Biographical Sketch.

THE professional career of Mr. Chanute fairly represents that of the typical American civil engineer, for, although born in France, in 1832, he came to the United States when about six years old, and was soon thoroughly Americanised.

He began his profession at the foot of the ladder, on the construction of the Hudson River railroad in 1849, by introducing himself to the resident engineer, and asking for employment. Upon being told that there was "no vacancy," he begged for permission to serve gratis "to learn the business," and this being granted after some urging, he considered his fortune made when, two months afterwards, he was appointed assistant chainman at $1.12½ per day. Nor was he far wrong, for this was the only place that he ever asked for, having been continuously employed for the ensuing thirty-six years, without soliciting either position or advancement.

He went to Illinois in 1853, and was

engaged on the construction and operation of various railroads, having been gradually promoted until he had become the chief engineer of the Chicago and Alton railroad in 1863, in charge of reconstruction and maintenance of way. This position he resigned in 1866,—being honoured by resolutions of regret from the directors of the road,—to take charge, as chief engineer, of the construction of the first bridge completed across the Missouri river,—that at Kansas City. This river had an ill-repute and, indeed, was pronounced unbridgeable by the pilots and dwellers on its banks, so that the successful opening of the bridge in 1869 was considered as a novel feat. An account of the methods employed was subsequently published in book form by the chief engineer, and his assistant, Mr. George Morison.

Mr. Chanute had nearly simultaneously been placed in charge of the construction of four railroads in Missouri and Kansas, an aggregate of about four hundred miles, and when these were completed in 1873 he was called to the chief engineership of the Erie Railway, which had been reorganised and had adopted plans for important extensions and improvements.

When he removed to New York in 1873, Mr. Chanute's attention was attracted to the fact that rapid transit had been discussed for about twenty years in that city without any adequate conclusion, or consensus of opinion, as to the methods which ought to be adopted to relieve the pressing necessity for better urban transportation. He proposed that this should be investigated by the American Society of Civil Engineers, and he was made chairman of a committee appointed for that purpose. Five months were spent in a careful study of the problem in examining all proposed schemes and conferring with many public bodies and private citizens. The report was made public in February, 1875. It advocated the building of four lines of elevated railroad, to be operated by locomotives, and it proved so convincing that legislation almost immediately followed. The roads were built and have since proved a great success, although they now require supplementing by additional facilities.

In 1883, Mr. Chanute resigned from the Erie Railway, and opened an office as consulting engineer, to promote the preservation of timber. He was the president, in 1891, of the American Society of Civil Engineers, and in 1895 received the distinguished honour of being elected an honorary member of the Institution of Civil Engineers of Great Britain. He has contributed many papers to the transactions of various societies of which he is a member. He was the presiding officer at the opening and closing sessions of the International Engineering Congress during the Chicago Exposition of 1893, and the chairman of the fifteen associated engineering societies which entertained foreign engineers who came to the United States during that exposition.

During the past six years he has devoted his leisure to an inquiry into the possibility of success in aerial navigation, not, as he says, in the expectation of solving the problem himself, as he holds that it will require a process of evolution, but in the hope of making the way easier for others. With this in view, he delivered a lecture before the students of Sibley College in 1890, and has since published a book on "Progress in Flying Machines," which is already quoted as a classic. He has also furnished funds from his own means to assist inventors to make experiments, and has made some of his own, to ascertain by what means absolute safety may be secured in the air.

Current Topics.

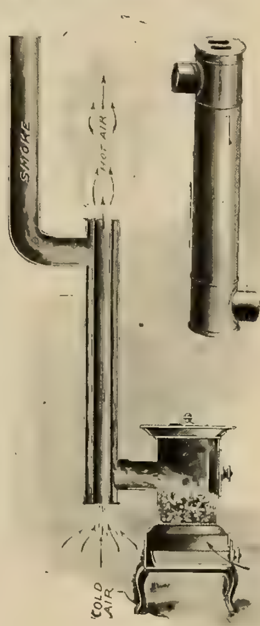
At last a use has been found for the unburnt ends of carbon taken from electric arc lamps. Mr. Johnston, the foreman of the smiths' and wood-working shops of the Baldwin Locomotive Works, in Philadelphia, has recently instructed the man who changes these carbons in the lamps throughout the works to save the partly consumed pieces and bring them to him daily. He gets in this way some sixty or seventy carbon stumps which he utilises for making a small charcoal fire of great heat and purity, suitable for any kind of special small work not interfered with by the copper coating on the outside of the carbons. Mr. Johnston having shown the way, others engaged in kindred lines of work ought to follow his example. It stands to reason that carbon prepared with so much pains to keep it pure and homogeneous, must be serviceable for some of the many uses for which charcoal is required. The copper coating might be an objection for some things, but if the collection of stumps were large enough, it might pay to remove the copper with nitric or sulphuric acid, thus getting an absolutely pure nitrate or sulphate of copper, for either of which there is always a practically unlimited demand in the arts.

The competition of Southampton for American passenger traffic has had a most beneficial effect upon the port authorities at Liverpool. Prior to 1890 when the rivalry of Southampton was first recognised as serious, the great sandbar at the mouth of the Mersey had only 11 feet of water upon it at the ebb of spring tides. After dredging at this bar in the ordinary way from 1890 to 1893, the Mersey Dock Board in the latter year put the great centrifugal suction dredge boat *Brancker* to work. This boat is 320 feet long by 46 feet 10 inches beam, has twin screws and can steam at the rate of 10 knots an hour. Her hoppers hold 3000 tons of sand, which, therefore, constitute the full load which she carries out to dump in deep water. Her suction powers are so enormous that under favourable circumstances she can put the 3000 tons of sand in her hoppers in 25 minutes, never taking longer than 45 minutes. She has a record of 39,000 tons of sand sucked and dumped in the twenty-four hours and of 183,000 tons in five and a half successive days. The result is that at ebb spring tides there is now a depth of 25 feet of water on the Mersey bar instead of 11 feet, as formerly. In all, 17,000,000 tons of sand were removed from the Mersey bar since 1890, the *Brancker* being assisted, since 1895, by a duplicate sister suction boat, the *G. B. Crow*. If the Federal government of the United States were alive to the needs of New York Harbour, two boats of this class would be set to work at the bar at Sandy Hook. Already many large merchant steamships draw 28 feet

of water, while a few, like most first-class battleships, draw 30 feet. The great shipbuilders of the world are quite convinced that the next move in the direction of increased speed for transatlantic liners must be increased draught, and 35 feet is frequently mentioned as a depth at which it would be possible to utilise economically more than 30,000 horse-power—the horse-power of the present *Campania* and *Lucania*. If New York's harbour were controlled by her citizens, a straight 40-foot channel from the Narrows to deep water would soon be made, just as the citizens of Glasgow have straightened and deepened the channel of the Clyde, or the citizens of Belfast have made an entirely new straight channel through the former shoal waters of Belfast Lough. Unfortunately, the imperative commercial needs of New York must wait while Senators and Congressmen at the American capitol fritter away the "River and Harbour Appropriation" in driblets upon places which have never had any seagoing commerce and which never will have any.

WHILE low coal and steam consumptions, in themselves, are very admirable things in boiler and engine practice, they do not by any means represent true measures of economical operation. There are other things to be looked out for in every power plant, whether ashore or afloat, and it is not the pounds of coal per horse-power per hour that really interest the owner of a factory or of a steamship, but the amount of useful service that he can get through the expenditure of a given sum of money. Whether that money goes into the coal pile or whether it is used up in repairs and maintenance of the machinery may well be a matter of entire indifference to him. The wear and tear and depreciation items, and interest on invested capital, however, are ever-present warnings against excessive refinements of plant. Whatever saving these may effect, either directly in coal, or in wages for boiler and engine room staffs, or in any other possible direction, may be completely swallowed up by augmented expenses peculiar to such refinements, and the question to decide is, in every instance, which of the two sets of expenditures will be the greater. It is a matter of very simple arithmetic; but its practical aspect is often allowed to become obscured.

SOME enterprising Frenchman brought out last year a stove-pipe design which ought to commend itself at once for adoption wherever stoves are used for heating apartments. The little sketch annexed, which has been reproduced from the *Revue Universelle*, explains the arrangement so very clearly that scarcely anything seems to be required in the way of further description. The vertical leg of the smoke flue, leading from the stove to the chimney, is traversed by two pipes, open at both top and bottom to the air in the room, and through these the air naturally circulates, becoming heated in its passage.



A FRENCH STOVE PIPE RADIATOR.

The efficiency of the smoke pipe as a radiator has thus been increased merely by the addition of heating surface, and that, too, in a very simple and direct manner.

BRITISH railways invariably show a considerable advantage over those in the United States in economy of coal consumption. This fact is somewhat reluctantly admitted even by some of

the best authorities on the American side. When it comes to assigning causes for this difference in coal consumption, however, every expert has his own theory. Perhaps it may not be amiss, under these circumstances, to refer to a time on British railways, not more than a generation ago, when there were such wide fluctuations in the coal consumption of similar engines hauling similar trains on the same road as to cause an investigation of the whole matter by various British locomotive superintendents. It was then found that economy of coal was dependent, other things being equal, on the method of firing. The wasteful plan was to drop each shovelful of coal just inside the door of the firebox and let it roll forwards and sideways to fill the gaps caused by combustion. The economical method was to spread the coal evenly over the bars of the grate, selecting six points at which the shovel was aimed in turn. These were the right and left front corners of the firebox, the right and left sides of the firebox, and the right and left back corners. It is obvious that, if skilfully done, this plan of firing left the centre of the fire rather thinner on the bars than it was around the sides, and it was from this fact that the two different methods of firing received their characteristic names, the first being known as "heap" firing and the second as "hollow" firing, or, sometimes, as "side" firing.

A CAREFUL, intelligent engine driver was certain, sooner or later, to realise the advantages of hollow firing, and to insist on his fireman carrying out his instructions on this point. On the other hand, a careless or incompetent man would let his fireman do as he liked, with the result that the fireman usually took the lazy and easiest way and went in for heap firing. From hollow firing as a beginning came many other discoveries. It was found that in heap firing the inrush of cold air on the tube plate, alternating with the hot gases of combustion, was a frequent cause of leaking tubes through the sudden extremes of contraction and expansion. When premiums were given to those engine drivers who were most economical in the consumption of fuel, observation taught those who were most anxious to be at the head of the premium list, that it made a difference, too, whether the fire was replenished on an embankment exposed to the winds or in a cutting sheltered from them.

How far hollow firing has decreased coal consumption it is impossible to say with exactness, yet some approximation toward it can be made. In the late D. K. Clark's great work on "Locomotive Engineering," published in 1860, it is laid down, as a rule, that the coal consumption of an ordinary passenger train might be reckoned at 14 pounds of coal per mile for the engine and tender, and 7 pounds of coal per mile for each passenger coach. Taking the average passenger locomotive of that date at 25 long tons weight, the tender at 15 tons, and five passenger coaches, two-thirds filled, at 12 tons each, would give us a hundred-ton train with an estimated coal consumption of 49 pounds of coal to the mile. It may be taken for granted that the speed of such a train would not exceed thirty miles an hour. The same careful authority, writing in 1885, or twenty-five years later, when hollow firing was firmly established, gave the weights, speeds and coal consumption of typical British passenger trains on the leading roads. Thus the Midland Railway's fast express trains between Manchester and Derby, consisting of an engine weighing 42 tons, tender weighing 26 tons, and seventeen carriages weighing 187 tons — all in working order, and making a gross weight of 255 long tons—were hauled on a time bill speed of 50 miles an hour, with a coal consumption of 28 pounds of coal per mile. The Great Northern "eight-foot single" engines, hauling trains of 224 tons, including the weight of the engine and tender, at a speed of from 50 to 53 miles an hour, consumed

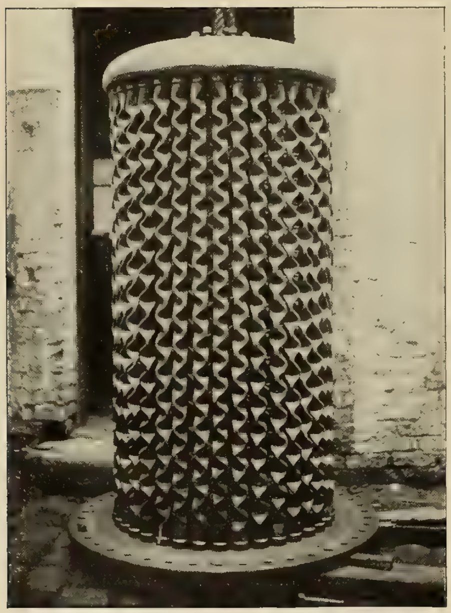
25¼ pounds of coal per mile. A London and North-Western four-wheel coupled engine, 17×24, with 79-inch wheels, hauled a gross load of 293 tons at a speed of 45 miles an hour with a coal consumption of 26¼ pounds.

Now, while the engines and trains thus described by Clark are running today in Great Britain, it is safe to say that no engines in the United States, doing similar work, approach them in economy of coal consumption. Indeed, there is positive knowledge of one well-known fast passenger train on one of the routes between New York and Chicago, with a gross weight not exceeding 275 long tons, where the coal consumption averages 75 pounds per mile. Moreover, from the fact that such a comparatively large coal consumption excites no special comment and that no extraordinary effort is made to reduce it, the fair inference is that it is not considered remarkable. And while figures in regard to the coal consumption of particular trains are easily obtained from British roads, accurate and reliable figures for similar trains on American roads are rare and difficult to get. It may be merely a coincidence that hollow firing is not much, if at all, practiced in the United States, and it is, doubtless, true that the unfortunate fireman of an express train who has to shovel in 75 pounds of coal to the mile has little time to do more than dump it in at the firebox door; or it may be that the inferiority of American coal to Welsh steam coal may account for at least part of the difference in the quantity used. Something, too, might be put down to the credit of the British locomotive in being more specialised and individual in type—that is, each class of passenger train, whether fast or slow, heavy or light, to make few stops or many, to climb over steep hills or to run on level roads, has an engine attached to it just adequate to the work to be done, and, therefore, working at maximum efficiency and economy. In any case the mystery remains, and will remain until some American superintendent of motive power makes a clean breast of the causes of which he must know the true reason.

Apropos of the much-discussed question as to the relative efficiencies of suction draught and forced draught for boiler furnaces, Mr. R. T. Napier, some months ago, in a communication to the Institution of Engineers and Shipbuilders in Scotland, made the point that the ideal state of matters in any boiler furnace is obviously when equal quantities of fuel are supplied with equal and sufficient quantities of air, and are burned in equal intervals of time. Anything interfering with this condition of things operates necessarily against efficiency. In tubular boilers a familiar source of interference is the tubes becoming foul. The quantity of air entering the furnace is thereby reduced, and its distribution is also affected, as the current of hot gas naturally seeks the side of the combustion chamber where the tubes are least obstructed. If it is found in practice that with suction draught the tubes require less attention in the way of cleaning than with forced draught, then the superior efficiency of the former arrangement is explained. It is reasonable to suppose that the pressure of gas inside a boiler tube under forced draught does not vary uniformly throughout, but that the difference of pressure per inch of length is greater at the combustion chamber end than at the smoke box end. It is also reasonable to suppose that with suction draught the case is reversed, and the difference of vacuum per inch of length is greatest at the smoke box end. If this be so, the "scour" through the tube in the former case will diminish from the moment a particle of dust enters or a particle of soot is deposited. In the latter case the "scour" will increase, and the tendency be to keep the tube clear. Suction draught is in its infancy, and matters more weighty than the fouling of boiler tubes are engaging attention, but the foregoing explanation of its superior efficiency is suggested

by Mr. Napier as being not an altogether unreasonable one.

SOMEWHAT less than four years ago an illustration and particulars were given in these pages of a then newly-introduced tube,—the Row tube as it became known,—intended for use in feed-water heaters. Since that time the tube has scored a decided success, not only for the special purpose just mentioned, but for service as well in evaporators and condensers, and in steam and hot water radiators, in all of which it appears to have demonstrated to the satisfaction of all concerned that it is capable either of heating water or of cooling it, and of condensing steam at about double the rate of a plain tube of equal area. The tube is full of indentations, very well shown in the annexed sketch, and its efficiency has been explained as due to the scouring action of the fluids on the irregular surface. That great increase in the efficiency of heating surface can be secured from this cause was strikingly shown, as some one stated it in a discussion before one of the engineering societies, by the difference of behaviour in locomotive boilers when working on the rails and when working stationary. When running on the rails, it was no uncommon thing for locomotives to work continuously and supply from 15,000 to 18,000 pounds of steam per hour at 160 pounds pressure, evaporating about 9 pounds of water per pound of coal, and working with a draught of from 6 to 8 inches of water. When the same locomotive, however, is put to stationary work on a fixed foundation, it is found difficult to get more than 4000 pounds of steam out of it, and if any attempt is made to increase the draught beyond, say, ¾ of an inch of water, trouble from leaky tubes at once begins. This difference in the rate of working was believed to be due to the fact that when running over the track, the mechanical vibration set up facilitated the delivery of steam from the heating surfaces, and this permitted them to be worked at a much more rapid rate. Facility for the removal of steam bubbles evidently plays an important part in the efficiency of the Row tubes; to the man who pays the coal bills, however, it is quite sufficient to know that with such tubes superior results can be obtained,—why or how, are matters of less importance to him.



A FEED-WATER HEATER WITH ROW TUBES.

WHAT Americans lack in the art of domestic economy they more than make up for in expertness in industrial economy. This, at least, is the opinion of one European engineer, a Frenchman, by the way, who recently returned from a tour of inspection through the United States. "Americans," he has been quoted as saying, "make money by saving wastage in business and lose some of it by wastage in domestic economy. The attention paid to small details in big works is amazing to me; I have visited some establishments where I believe that the profits are made not in the manufacturing proper, but in the saving of materials and labour by close attention to details that are with us unconsidered trifles. For example, I saw

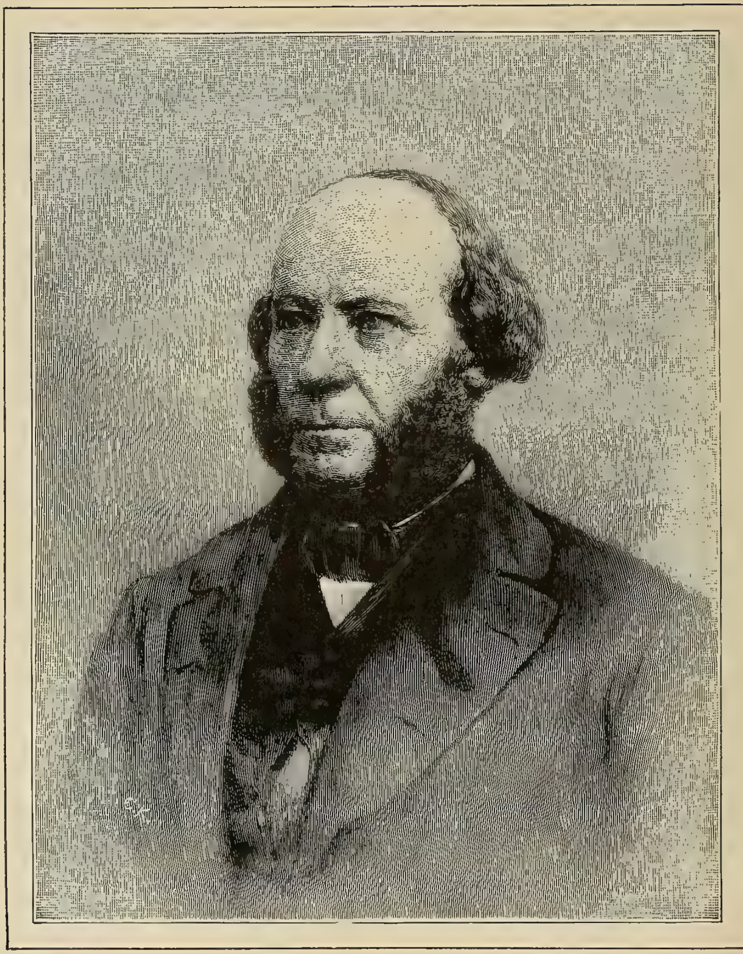
a little grindstone in operation at a big works automatically sharpening lathe and planer tools. This machine costs probably as much as a hundred of our ordinary grindstones cost, but I see that it automatically grinds all the tools for three hundred high-priced mechanics, and it only works a few hours each day. The skilled mechanics in our country frequently stop their regular work to grind their own tools, and then they do it imperfectly. In the United States tools are all accurately ground to the best shape by the machine, so that they do more and better work on this account in a given time. I believe that that machine has brains—the brains of the inventor—and it has no doubt revolutionised work of this kind in American machine shops. This is but one case out of many that I have noted."

QUITE in the line of what was said in these pages a few months ago regarding the folly of working to half-a-dozen decimals in figuring out the results of the average engineering experiment, come some recent remarks by Professor Kennedy, made in the course of a lecture before the British Institution of Civil Engineers. Professor Kennedy took for his objective point the carrying out of a marine engine trial at sea,—a problem quite as complicated as any likely to be encountered in engineering practice. When, as he pointed out, it is considered that the final result of such a trial depends on the accuracy of our knowledge of the dimensions of the steam engine itself, and of the steam engine indicators, on the uniform elasticity and the proper scale of the indicator springs, the accuracy with which the revolutions are observed, the accuracy of timing on the mile and of observing the distance at the same time, it will be seen how entirely out of the question it is that the figures obtained, even for a single run in one direction, should admit of statement in, say, more than three figures. When to this is added the uncertainty of the method of averaging speed as between a number of runs under different conditions as to tide and wind, the matter becomes still more striking. Or, when coal and water are also to be measured, and the weighing or measuring of both, and the calibration of all the heavy apparatus used for the purpose, as well as the personal errors due to making observations of large quantities under awkward physical conditions, in a minimum of time and in the worst of atmospheres, are considered, the uselessness and indeed the actual inaccuracy of extremely minute figures become absolutely glaring. It is often convenient, no doubt, under these conditions, to work out results to four significant figures for the sake of mere arithmetical checking; but no one who has had anything to do with the matter would suppose for a moment that more than three figures were of the least importance. Such an experiment ought to be undertaken with a distinct recognition of its limitations and of the limitations of accuracy of result such as have just been roughly indicated.

LOCATING an obstruction in an underground pneumatic tube line half a mile long was done at Philadelphia several months ago in a simple and effective manner by the application of acoustic principles. The line connects the general post-office of Philadelphia with a substation in the banking district in the city and consists of cast iron pipes, bored smooth, and about six inches in diameter. Light steel cylinders or carriers are forced through these tubes by compressed air. After having been in successful operation for over four years, a break occurred in the pipe system, presumably through settlement in the ground, and obstructed the passage of two of the carriers. Several attempts were made to locate the position of the obstruction, but without success, until, finally, Mr. B. C. Batcheller, chief engineer of the Pneumatic Transit Company, of Philadelphia, decided to make another trial by firing a pistol into the end of the pipe, and noting the time that elapsed between the discharge of

the pistol and the sound of the echo reflected back from the obstructing carriers. Knowing the velocity of sound and the time that it takes it to travel along the tube to the carriers and back again, a very simple computation would give the exact location of the carrier from which the sound was reflected. The problem that confronted Mr. Batcheller was to measure with precision this short period of time. Since sound travels with a velocity of about 1100 feet per second, it became necessary to measure the time accurately to a thousandth of a second. How this was done Mr. Batcheller has told at some length in the *Engineering News*, going into interesting details concerning the arrangement of the measuring apparatus. But all this, unfortunately, cannot be reproduced here. A street excavation, made on the strength of the first rough measurements with the instruments, came within twenty feet of the actual break in the pipe, while the carriers themselves were found almost exactly at the point where the workmen had been told to begin digging. The method which Mr. Batcheller followed was probably first used in Paris for locating obstructions in the pneumatic tube system of that city. What its limits are, in point of distance, it is impossible, at present, to say; a good deal, of course, depends upon the diameter of the tube and the ease with which sound waves will travel in it. In a 12-inch tube, for example, according to Regnault, the report of a pistol cannot be heard at a distance of 12,500 feet, or about 2¼ miles.

Apropos of the earth's store of fuel and the probable length of time that it will last to supply man's needs, it is interesting to recall the statement recently made by Lord Kelvin, while in the United States, that the danger ahead is not that the coal will give out and leave the world to freeze, but that the oxygen, which, of course, is destroyed along with the consumption of fuel, will all be used up and leave that helpless being, man, to a fate no kinder than asphyxiation. Of course, the creature must have his oxygen, and the only chance for his ultimate security, in Lord Kelvin's mind, is dependent on his capacity to create oxygen as well as to cause it to be consumed. The manner of manufacturing oxygen thus being something for the world to think about, the wherewithal of man's primary means of subsistence, necessary even before his food, is a much more important matter than the fuel which shall keep him warm. Lord Kelvin emphasised, therefore, that the best known system of producing oxygen, that of cultivating, in a broad way, vegetation, be adopted to avert the great disaster. What little danger there was to be feared from fuel scarcity would, he thought, probably be still further diminished by future geological exploration which would yield, no doubt, much now unthought-of information regarding the coal of the earth, notably of the contents of the soil in the depths of the sea. There might be much fuel there which could be consumed.



J. Ericsson

FROM A PHOTOGRAPH AT THE TIME HE BUILT THE "MONITOR."

CASSIER'S MAGAZINE.

VOL. XIII. APRIL, 1898. No. 6.

THE UNITED STATES IRONCLAD "MONITOR."

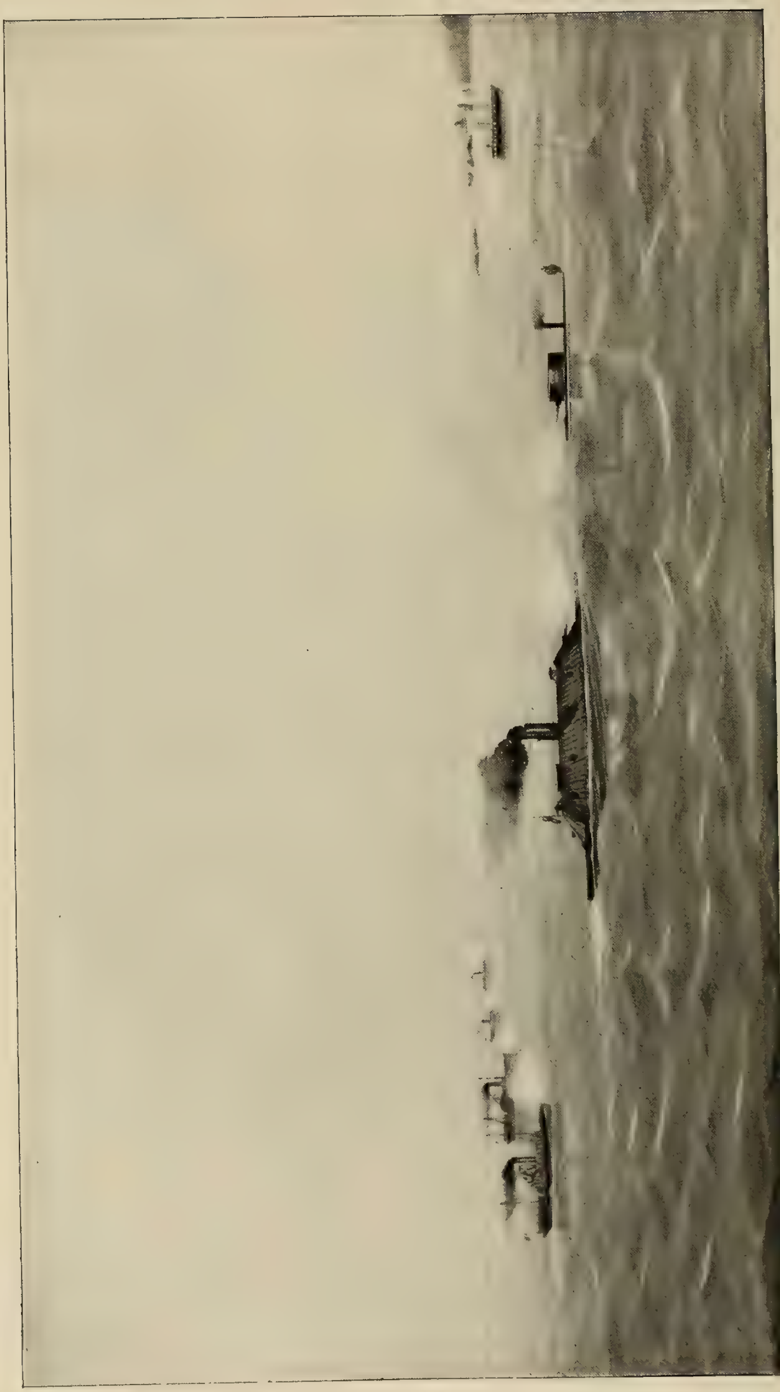
By F. M. Bennett, Passed Assistant Engineer, U. S. N.

THE recent death of Rear Admiral John L. Worden, of the United States Navy, has revived interest in the peculiar fabric with which he served his country so well, and to which he owes his fame. The story of the sea-fight in Hampton Roads during the American Civil War has been told again by the magazines and newspapers, and its effect upon war-ship construction all over the world has been pointed to anew. With the interest in the fight itself exists an interest in the *Monitor* and the man who made her. This other, or concurrent, interest is the one that appeals most directly to the readers of this magazine, because the story is an epic of the "The Tools and the Man" rather than of "Arms and the Man," and the former in this century is, as Thomas Carlyle has truly said, "an infinitely wider kind of epic."

Of John Ericsson it is hardly necessary to speak. The foremost man of his time in his profession, his fame is secure for all time, and the story of his achievements is too well known to need re-telling. His influence upon American history, exerted through the medium of the *Monitor* alone, was remarkable and has been fully recognised by historians. As eminent an authority as Dr. John Fiske, in his "History of the United States," concludes the account of the famous iron-clad duel with this reflection:—"Among the great men who saved the Union and freed the slaves, one of the most important was the man of science, John Ericsson."

In associating Ericsson with the *Monitor* we must not forget that that was only one of many notable achievements by him, though in far-reaching results it was his greatest. His active professional life extended over a period of about sixty years, in all which time he worked like a steam engine every day of every year and never rested until in his grave. His contributions to the scientific knowledge of his country greatly exceeded in number and variety those of any of his contemporaries. His application of the screw propeller to the United States sloop-of-war *Princeton* more than fifty years ago produced a change in naval construction as general, though not so radical, as that following the success of the *Monitor*.

We are so accustomed to the locomotive that the story of the Stephen-



REPRODUCED FROM A PAINTING BY PERMISSION OF B. A. RICHARDSON, NORFOLK, VA.

THE BATTLE BETWEEN THE "MONITOR" AND THE "MERRIMAC" IN HAMPTON ROADS, VA., ON MARCH 9, 1862.

sons and the first trial of railway engines seems almost far enough away to be ancient history. Yet, as showing the length of a busy life, and as a binding link between the past and the present, we must remember that the Ericsson, whose locomotive *Novelty* competed so well with Stephenson's *Rocket* in the famous Rainhill contest as long ago as 1829, was the same John Ericsson of the *Monitor*, and who died here among us only a few years ago.

The mechanical and structural features of the *Monitor*, rather than her military career, will form the subject of this essay. The drawings here reproduced are from those made in Ericsson's office and from which the *Battery*, as she was first known, was actually built. A provision of Ericsson's will required hat all his papers, drawings, journals,

THE ORIGINAL "MONITOR."

everything that bore upon his career, be destroyed. This wish was carried out too well, and thus much of great value to history and our profession was lost. Some of the original drawings of the *Monitor*, though unfortunately a very incomplete set, were saved from the general destruction by Professor C. W. MacCord, of Stevens Institute, who had been chief draftsman in Ericsson's office at the time the vessel was built. To the courtesy of Professor MacCord the author is indebted for the use of several of these drawings, the magnitude of the obligation being measured by the fact that they have never before appeared in a public print.

The use of iron for armouring war vessels was not a novel idea in 1861. The *Stevens Battery*, intended to be shot and shell-proof by iron armour, was still unfinished, but dated as far back as 1842. Three iron-plated floating batteries had been used by the French in the Crimean war. Both England and France had put light iron plates on large frigates and each country was building a dozen or more similar ships. The *Warrior*, *Black Prince*, and *La Gloire* were types of these vessels, which were full-rigged ships with auxiliary steam power, sail rather than steam being the real motive power. The Secretary of the United States Navy (Mr. Gideon Welles), in reporting the state of the navy to Congress in July, 1861, remarked upon the use of armour in other countries, and asked authority to build armoured vessels should such construction be recommended by a competent board of officers after investigating the subject.

Congress responded by an act, approved August 3, 1861, authorising the Secretary to appoint a board of three officers to investigate the question, directing him to have built one or more "iron or steel-clad steamships or steam batteries" should the report of the board be favourable, and appropriating one million, five hundred thousand dollars to execute the work. An advertisement was at once issued by the United States Navy Department asking bids from responsible persons for the construction of iron-clad steam vessels of war, of dimensions and qualities stated in general terms in the advertisement. Descriptions and drawings of all proposals submitted were required, and twenty-five working days from date of advertisement were allowed for the presentation of plans.

A board composed of two commodores and one commander, all officers

of distinction, was appointed to consider and report on the plans. It should be stated that the highest rank in the United States Navy then was that of captain. The senior captains when commanding shore stations or squadrons were by custom addressed as commodore, and having once had that title, retained it ever after, also by custom. The report of this board is a fair exposition of the naval and scientific beliefs of the time. The world has advanced so much in mechanical knowledge since then, though the actual time is but a generation, that the gravely recorded opinions of the board are interesting. For this reason a few quotations are here made.

"For coast and harbour defense they (iron-clad ships) are, undoubtedly, formidable adjuncts to fortifications on land. As cruising vessels, however, we are skeptical as to their advantage and ultimate adoption."

"The enormous load of iron, as so much additional weight to the vessel; the great breadth of beam necessary to give her stability; the short supply of coal she will be able to stow in her bunkers; the greater power required to propel her; and the largely increased cost of construction, are objections to this class of vessels as cruisers, which we believe it is difficult to overcome."

"From what we know of the comparative advantages and disadvantages of ships constructed of wood over those of iron, we are clearly of opinion that no iron-clad vessel of equal displacement can be made to obtain the same speed as one not thus encumbered, because her form would be better adapted to speed."

"As yet we know of nothing superior to the large and heavy spherical shot in its destructive effects on vessels, whether plated or not." It is assumed that 4½-inch plates are the heaviest armour a sea-going vessel can safely carry."

THE LATE REAR-ADMIRAL JOHN L. WORDEN, U. S. N., COMMANDER OF THE "MONITOR" DURING THE FAMOUS BATTLE

This board reported on seventeen propositions for armoured vessels. Some of these were submitted by engineers and shipbuilders of established reputation, and others by unknown patriots who might, in the richer vocabulary of the present, be styled "cranks." One genius, without entering into details of size or cost, proposed a *rubber-clad* vessel, which the board solemnly averred it could not recommend. The plans ranged all the way from 90 tons to 15,000 tons displacement, and the estimated cost from $32,000 to $1,500,000. From these proposals the board selected three and recommended that contracts be made with the bidders as follows:—

With C. S. Bushnell & Co., of New Haven, Conn., for an iron-clad gunboat on the rail and plate principle, the resulting vessel being the first *Galena*.

With Merrick & Sons, of Philadelphia, for a large wooden ship with iron citadel, subsequently named *New Ironsides*.

With John Ericsson for the *Monitor*.

It was only by a train of accidental happenings, too long to tell in detail, that the plan of the *Monitor* ever came before the board and was accepted. When Mr. Bushnell learned that his plan for the *Galena* would be accepted

he went to New York to consult Ericsson about the details of the vessel he expected to build. Ericsson exhibited to him a model showing the principles of the *Monitor*, the model being a modification of one he had submitted to Emperor Napoleon III. in 1854.

The Napoleon model had a shield or "turtle-back" deck, and its turret was in the form of a hemisphere. Mr. Bushnell observed the possibilities of the model and by taking advantage of personal acquaintance laid it before Secretary Welles, who happened, by good luck, to be in Connecticut at the time. Soon thereafter Mr. Bushnell took the model to Washington and exhibited it to the armour board, where it excited some interest and was then rejected. Bushnell induced Ericsson to make the journey to Washington and explain his design, which Ericsson did with such eloquence and masterly show of knowledge that his plan was accepted and he was told to proceed at once with the construction. With the energy for which he was famous, Ericsson had material for his vessel going through the rolling mills in the few days that elapsed before the formal contract was prepared.

The contract, dated October 4, 1861, required Ericsson and his sureties to build an iron-clad, shot-proof steam battery, of iron and wood combined, of dimensions stated in general terms in the contract. A sea speed of eight knots per hour, to be maintained for twelve consecutive hours, was stipulated. The contract price was $275,000, to be paid in five instalments of $50,000 each, and one of $25,000, payments to be made as often as the superintendent of construction should report that the progress of work warranted. A reservation of 25 per cent. was withheld from each payment, to be retained until after the satisfactory trial of the

A PORTRAIT GROUP ON THE "MONITOR'S" DECK, TAKEN BEFORE THE BATTLE.

A DECK VIEW OF THE "MONITOR" FROM A PHOTOGRAPH TAKEN BEFORE THE BATTLE.

vessel, not later than ninety days after she should be ready for sea. The superintendent of construction of the entire vessel was Chief Engineer Alban C. Stimers, United States Navy. The capitalists who became Ericsson's sureties were Messrs. C. S. Bushnell, John A. Griswold, and John F. Winslow.

One clause of the contract provided that if the vessel failed to make the specified speed, or should be wanting in other respects, the contractors should refund the full amount that had been paid them. This provision is the basis of the widespread fiction that Ericsson and his sureties paid for the building of the *Monitor* out of their own pockets, and were reimbursed only after she had proved her worth in battle. Fact is, that every payment was made according to contract before the vessel left New York and the 25 per cent. reservation was paid within a week after the famous duel in Hampton Roads. Her performance on that occasion was considered satisfactory, though her speed was not up to contract requirements.

Another requirement of the contract shows how reluctant the naval experts of that day were to admit steam on board ship on any terms except as an adjunct. It required the contractors to "furnish masts, spars, sails, and rigging of sufficient dimensions to drive the vessel at the rate of six knots per hour in a fair breeze of wind." Ericsson's ideas of stability as applied to light-draft vessels did not agree with this requirement, and he did not observe it; nor does it appear that the naval officials attempted to enforce it. At any rate, the *Monitor* was a steamer pure and simple, without mast, spar, or sail. Not many years later the top-hamper of masts and sails on a low-freeboard turret-ship gave the British Navy the tragedy of the *Captain*.

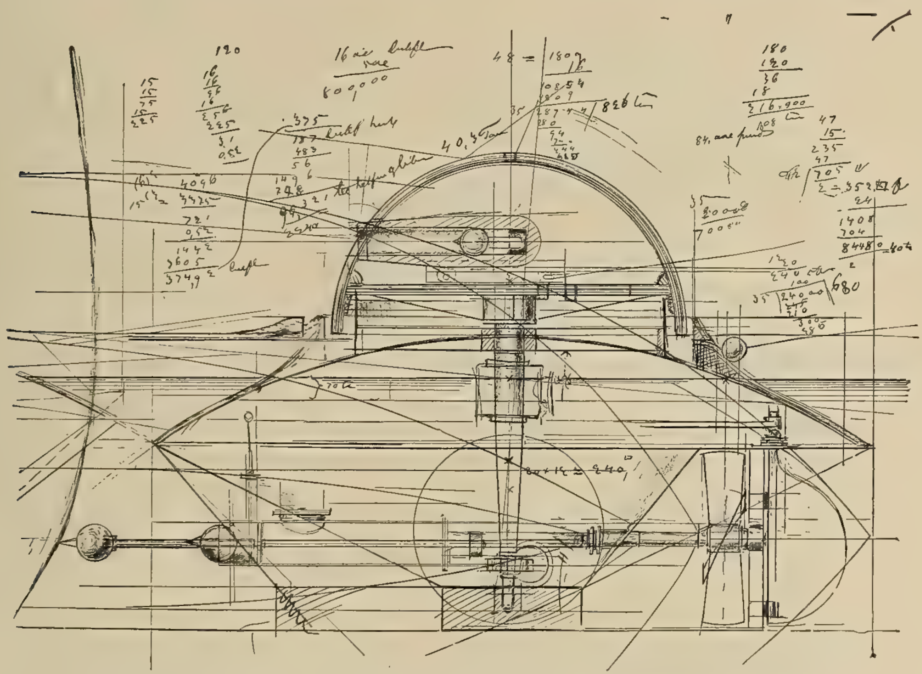
The name *Monitor* was given by

Ericsson himself, as shown by the following letter written by him in January, 1862, to Assistant Secretary of the Navy G. V. Fox:—

"SIR—In accordance with your request, I now submit for your approbation a name for the floating battery at Greenpoint. The impregnable and aggressive character of this structure will admonish the leaders of the Southern Rebellion that the batteries on the banks of their rivers will no longer present barriers to the entrance of the Union forces. The iron-clad intruder will thus prove a severe monitor to those leaders. But there are other leaders who will also be startled and admonished by the booming of the guns of the impregnable iron turret. 'Downing street' will hardly view with indifference this last 'Yankee notion,' this monitor. To the Lords of the Admiralty the new craft will be a monitor, suggesting doubts as to the propriety of completing those four steel-clad ships at three and a half million a piece. On these and many similar grounds, I propose to name the new battery *Monitor*."

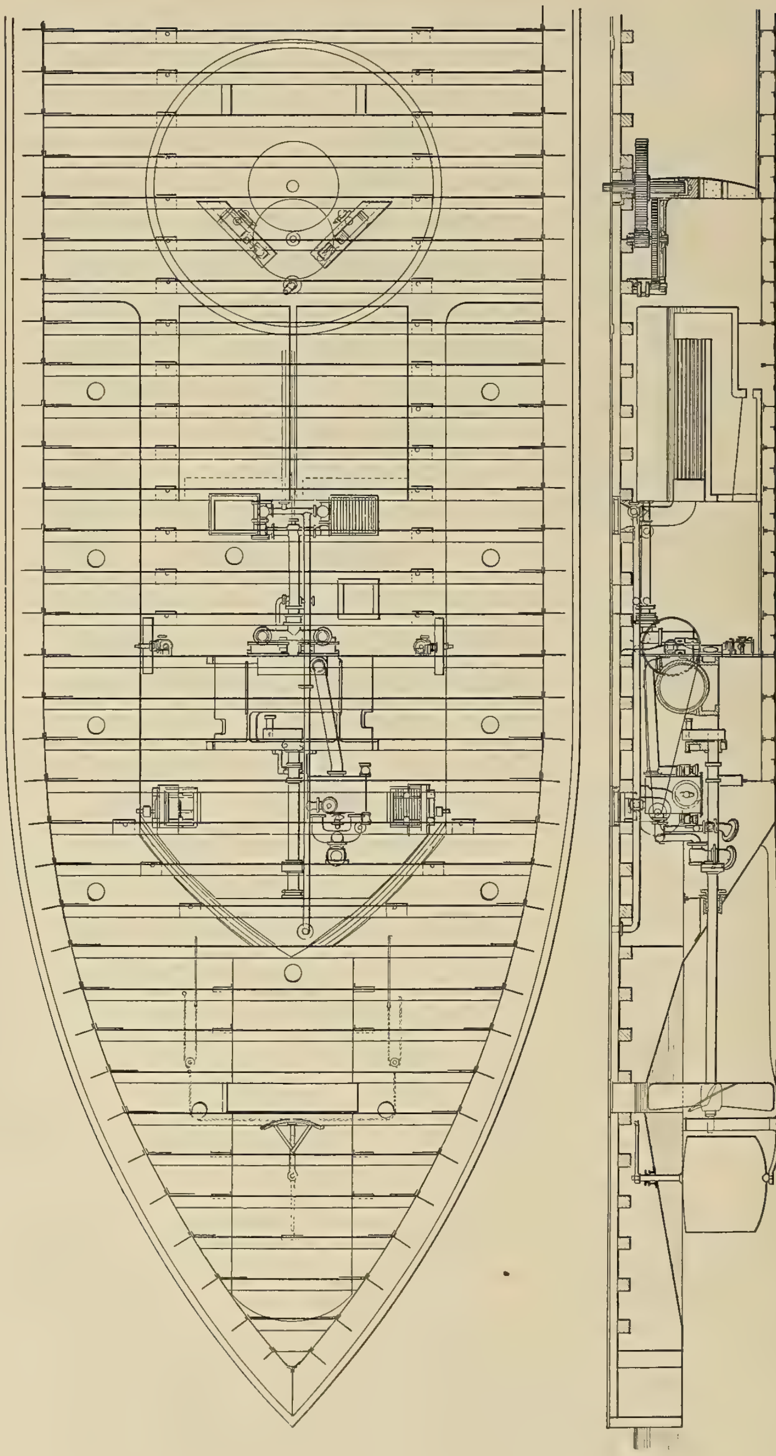
Every detail of this epoch-making craft sprung from the vigorous brain of John Ericsson, and his restless energy rushed the work forward with unprecedented rapidity. Hull, machinery, turret, gun-mounts, all that was in her, in short, grew from his designs. Working drawings, often rude and only in pencil, went from his table to his aids to be perfected, or directly to the workshops, almost as fast as sheets from a printing press.

To hasten the work to the utmost, it was parcelled out to many contractors.



FACSIMILE OF A PENCIL SKETCH BY CAPTAIN ERICSSON, GIVING A TRANSVERSE SECTION OF HIS ORIGINAL "MONITOR" PLAN WITH A LONGITUDINAL SECTION DRAWN OVER IT.

The hull was built by Thomas F. Rowland at the Continental Iron Works, at Greenpoint, N. Y.; the main engines and auxiliary machinery were built by Delamater & Co., of New York; and the turret came from the Novelty Iron Works, also of New York. The turret was built up of eight layers of one-inch iron plates, bolted together. Many lesser establishments contributed to the



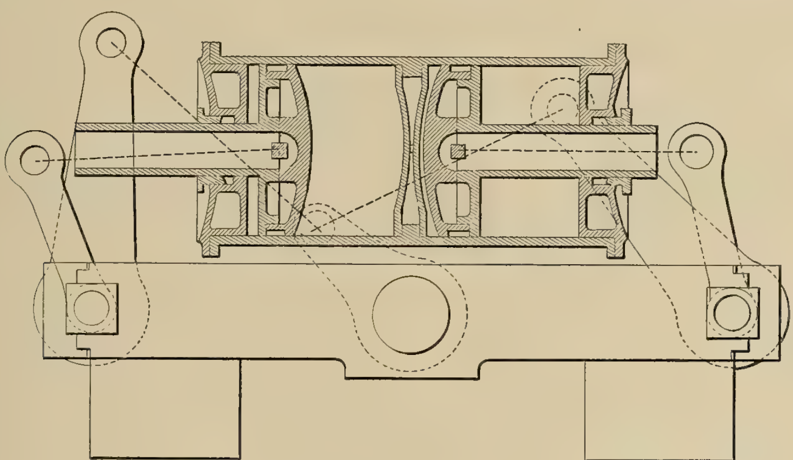
PLAN AND VERTICAL LONGITUDINAL SECTION OF ONE END OF THE "MONITOR," SHOWING THE LOCATION OF BOILERS AND ENGINES, AND THE ARRANGEMENT OF STEERING AND TURRET TURNING GEAR. REPRODUCED FOR THE FIRST TIME, FROM ONE OF CAPTAIN ERICSSON'S ORIGINAL DRAWINGS, THROUGH THE COURTESY OF PROFESSOR C. W. MAC CORD.

work by sub-contracts for bolts, rivets, and other material. Ericsson hoped for 15-inch guns, but they could not be made in time. The ship was launched on January 30, 1862, with her main engines installed on board; this was 101 working days from the date of contract.

The dimensions of the vessel as built followed closely the figures named in the contract. The extreme length was 172 feet; extreme beam, 41 feet 6 inches. The iron hull was 124 feet long, 18 feet wide at the bottom, and 34 feet wide at its junction with the armour raft, or upper body; depth of hold 11 feet 4 inches; mean draft, 10 feet 6 inches; inside diameter of turret, 20 feet; height of turret, 9 feet; displacement, 987 tons. The deck was covered with iron plates one inch thick, and the sides of the upper body had five inches of iron armour.

The upper body was a sort of wooden raft on top of the iron hull. It is difficult to describe this arrangement to any one not familiar with ship construction. An elongated shallow tin pan with a heavy, iron-bound plank of the same shape, but considerably longer and somewhat wider, laid on top of it and the combination set afloat may give the general idea. Ericsson himself described the invention as a fort on a raft. It was not pretty, nor "ship-shape," according to the notions then prevalent; but it was the germ of the modern battleship.

The top of the turret was made of bars of commercial railway iron, two small openings being left for escape hatches. The turret was large enough to permit of loading the gun at the muzzle when it was run in. During this operation the gun ports, as shown in the illustration on page 472, were screened by huge iron pendulums, hanging from the top of the turret, suitable eye bolts and tackles being provided for heaving these pendulums aside when the guns were to be run out. The pilot house, built log-cabin fashion, of heavy iron billets, 9×12 inches, with the corners dovetailed and bolted, was far forward on deck, with no communication with the turret except a speaking tube. This voice pipe was found unreliable, and the position of the pilot house prevented ahead firing. In all monitors built afterward, the pilot house was put on top of the turret.



CAPTAIN ERICSSON'S DOUBLE-TRUNK, VIBRATING-LEVER "MONITOR" ENGINE. 1862.

Ericsson's favorite form of steam engine was that described as the vibrating-lever type, by which a rocking or oscillating motion was changed to rotation by means of connecting rods. His first application of this was the rather remarkable half-cylinder engine with swinging "barn-door" piston, put in the *Princeton* in 1843. Double-trunk

cylinders followed this, and the final development appeared in the great 100-inch engines of the *Dictator* and *Madawaska*, of the United States Navy, in which the steam cylinders were not different from other practice, but still transmitted power by the rocking arms.

The *Monitor* had the double-trunk engines, shown in general outline by the sketch on the preceding page. The cylinder, or cylinders, for there were really two, though only one casting, were 36 inches in diameter, and 27 inches stroke of piston. The wall between the two cylinders and its properties of transmitting heat became the subject of a professional controversy, hotter than itself, between Ericsson and Benjamin F. Isherwood, at that time engineer-in-chief of the United States Navy, but "that is another story."

There were two return-tube "box" boilers, placed side by side, forward of the engines, each containing two furnaces, joined to the back combustion chambers by large oval flues. The height of the boilers from water-bottoms to top of shell was 9 feet, from which it will be seen that they occupied practically all the vertical space between the deck and the bottom of the ship. Each boiler, as shown in the plan and section on page 466, discharged its smoke through a short uptake to a grated hole flush with the deck, there being no smokepipe. The object of this was to avoid an obstacle to firing the guns. In all subsequent monitors smokepipes were provided.

Without air downtakes or ventilators, a mild forced-draft system had to be resorted to. This was supplied by two steam engines driving, by belting, two large blowers which discharged air into the engine and fire-rooms, whence it had no egress except through the furnaces. Air for the blowers was drawn from grated openings in the deck similar to those provided for the escape of smoke. The object of the gratings, of course, was to prevent missiles and débris falling into the blowers or boiler uptakes. Low iron coamings, or trunks, about five feet high, were provided to exclude water from these deck openings in a seaway. When cleared for action these trunks were to be unshipped, leaving the deck entirely clear, except for the pilot house.

The anchor, instead of being catted and fished to the usual position on the edge of the upper deck forward, was arranged to be hove in by its own chain to a recess in the forward overhang. From there it could be worked by simply heaving in or veering chain, without endangering men on the low deck in rough weather or in presence of the enemy. In this position also it was out of the way and was safe from being carried away by shot. Ericsson regarded this protection of the anchor as an important feature, and later greatly resented adverse criticism of naval captains regarding it.

On February 19, three weeks after launching, the *Monitor* had a trial trip that was such a failure that she had to be towed home. Almost everything went wrong. This is not to be wondered at, however, when we remember how rapidly the structure had been assembled and that it was composed of many pieces from many workshops, made from rough plans. The trouble with the propelling engines was charged to faulty valve-setting and was easily remedied. Both gun mounts were disabled because the guns were fired without compressing the friction gear by which the recoil was to be taken up, but the damage was small considering the possibility for a general smash-up.

The greatest defect was the lack of control of the vessel by the steering gear. The rudder, of the balanced type, was over-balanced; that is, the area forward of the rudder post was too great in proportion to that abaft it. Consequently when the rudder was put over either way, the forward section offered so much resistance to being thrown back again that the mechanical connection between the steering wheel and the tiller was unequal to the work. The naval authorities proposed docking the ship and replacing the rudder with one of better proportion, but Ericsson fiercely opposed this. It is well that his objection prevailed, for had the delay of

fitting a new rudder been incurred the *Monitor* and *Merrimac* would not have met when they did; and they might never have met.

According to his biographers, Ericsson burst into a furious rage when this proposition was made known to him. With a mighty oath he is said to have shouted:—

"The *Monitor* is MINE, and I say it shall not be done!"

He added presently, in a tone of contempt:—"Put in a new rudder! They would waste a month doing that; I will make her steer as easily in three days."

He did remedy the trouble within three days, though he did not correct the original fault in the shape of his rudder. The change consisted simply in doubling the purchase between the tiller and the wheel ropes. This was a makeshift in an emergency that any seaman or mechanic should have thought of.

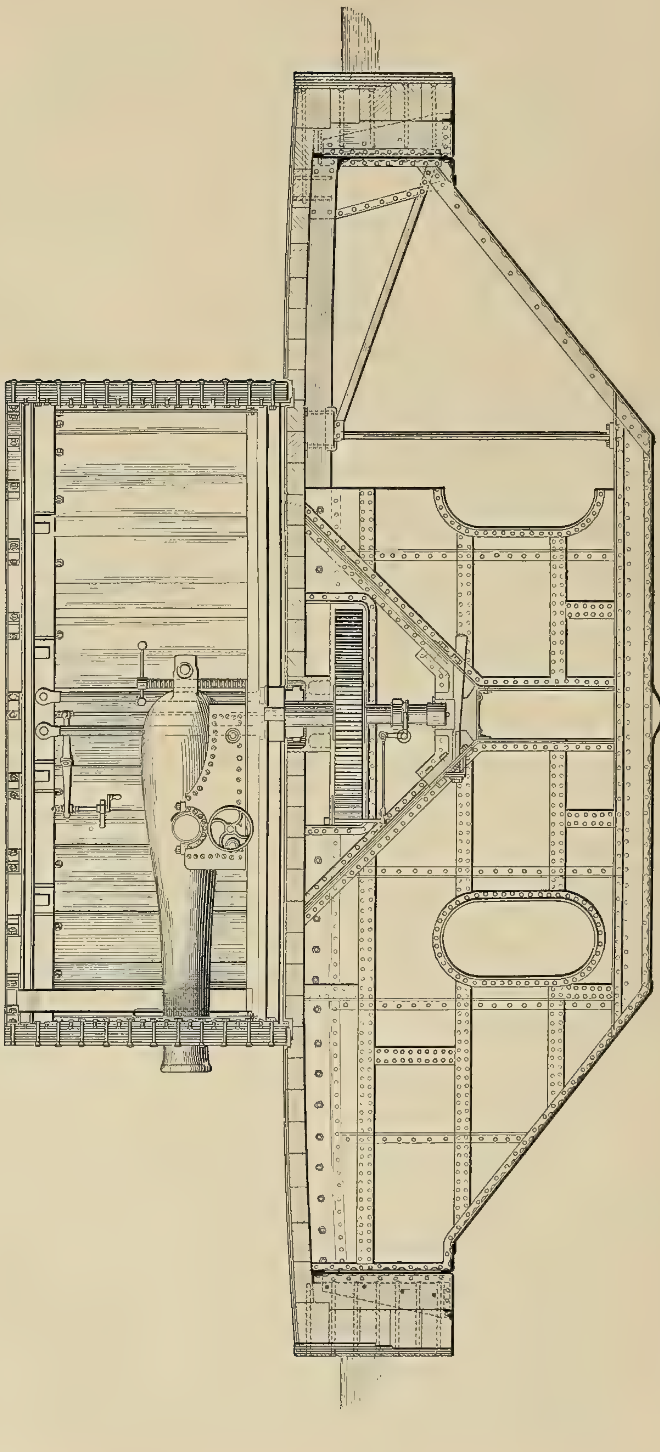
The first trial trip developed faults that were to be expected in such a hastily-built craft. These were remedied within two weeks, and on March 4 a final, and successful, trial trip was run, the guns were satisfactorily tried, and a favourable report was made by a board of naval officers. Two days later she went to sea under convoy and in tow, though using her own steam as well. She had been formally commissioned on February 25 under command of Lieutenant John L. Worden, United States Navy. Twelve officers and forty-five enlisted men comprised her personnel. Chief Engineer A. C. Stimers, the superintendent of construction, went to sea in the vessel to observe her performance and give the officers the benefit of his knowledge. He was, as stated by Colonel W. C. Church, in his "Life of John Ericsson," "the only man on board who thoroughly understood the characteristics of the vessel."

The voyage to Hampton Roads was eventful and almost ended the career of the *Monitor*, and with it the fate of ironclads for an indefinite time. Rough weather was encountered, and water broke over the smoke and blower trunks, nearly putting out the fires and stopping the pumps from lack of steam for four or five hours on one occasion. Loss by foundering was imminent at this time because of the great quantity of water that got into the vessel under the base of the turret and through the hawse pipes. The blowers stopped because the belts got wet and the engine and fire-rooms filled with noxious gas from the fires and had to be abandoned. In trying to remedy this trouble, the chief engineer, Mr. Newton, and his assistants were overcome by the gas and were carried to the top of the turret where they revived, though they were thought dead when dragged out of the engine-room. Trouble and danger also resulted from the wheel-ropes jumping off the steering wheel and becoming jammed.

After two days of toil and peril the *Monitor* escaped from the dangers of the sea into the presence of a new enemy. Late in the afternoon of March 8 she passed in at the Capes of Chesapeake, and from the sound of shotted guns knew that her time for action had come thus early in her career. The *Merrimac* was abroad that very afternoon, and wreck and destruction fouled her wake. A rude improvised ironclad herself, she marked a new era in naval warfare, and before her a large fleet of supposedly formidable ships of war was as helpless as a flock of sheep assailed by a wolf.

Night fell before the *Monitor* came up to the seemingly doomed Union fleet in Hampton Roads. The *Merrimac* had glutted her thirst for blood for the day and was at anchor and at rest, but in her silence in presence of the ships that she meant to attack in the morning she stood for all that men understand by the dominion of the seas. Lighted by the burning wreck of the frigate *Congress*, the *Monitor* moved up toward Newport News and anchored near the stranded *Minnesota*, upon which vessel, it was certain, the first blow of the morrow would fall.

From either an historical or a theatrical point of view the stage settings were now complete. With the night the curtain had fallen upon the last of a long series of glorious deeds, performed



TRANSVERSE SECTION THROUGH THE TURRET OF THE "MONITOR," REPRODUCED FROM A HITHERTO UNPUBLISHED ORIGINAL DRAWING BELONGING TO PROFESSOR C. W. MAC CORD.

under an order of seamanship, or sea tactics, that had already long passed its meridian, but which, for romance and chivalry, excelled any that had preceded it, and, it must be admitted, excelled that which was now to rudely supplant it. A new type of sea-warrior and a new type of war ship were about to appear upon the waters. The engineer's machine of John Ericsson was to face the fabric that represented the engineering ingenuity of the American South, and the result of the encounter would inflict fright upon the romance of the sea and transform the masted navies of the world into useless relics in a day.

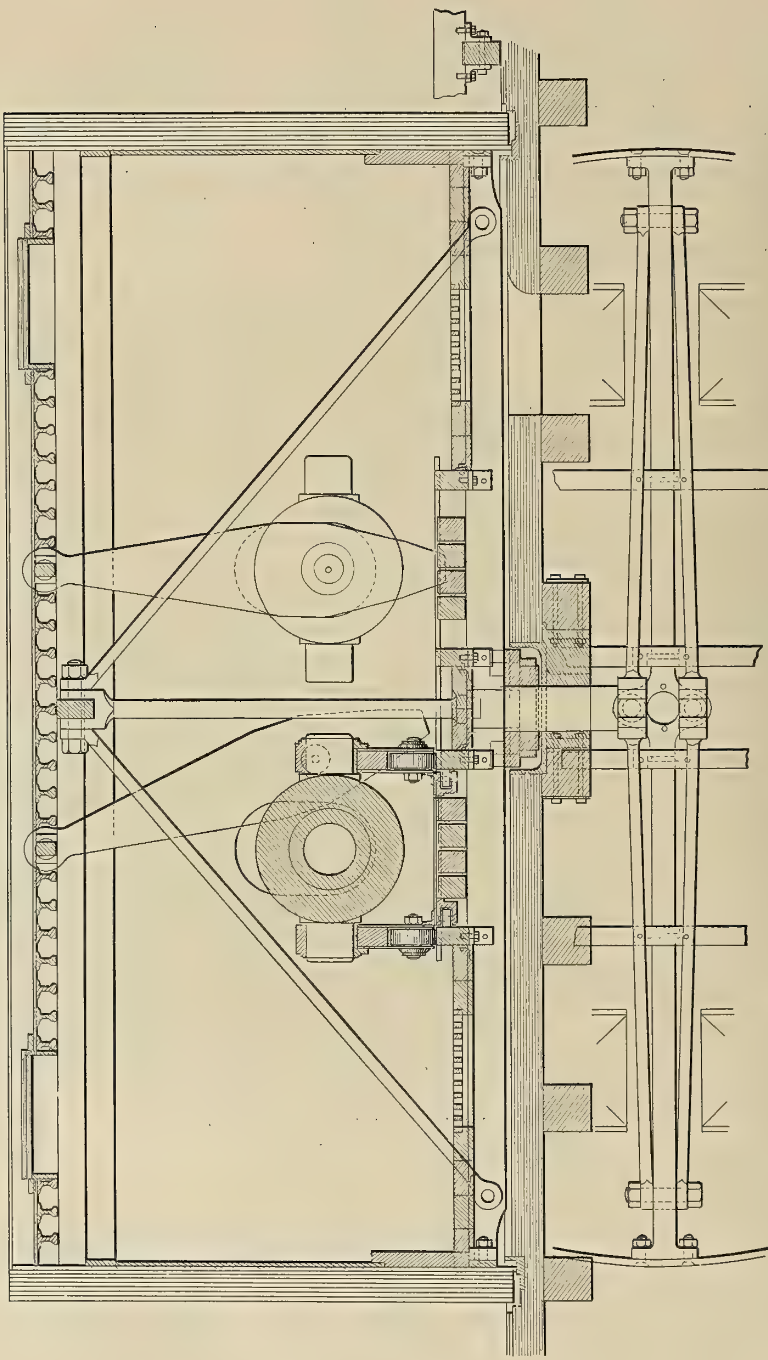
It is not within the scope of this article to tell the story of the famous sea-fight in detail. The *Merrimac* got under way on Sunday morning, March 9, with the intention of destroying the Union fleet lying at her mercy. When she advanced to attack the *Minnesota*, the *Monitor* came out from behind the big frigate and assumed the rôle of defender. In the furious duel between the ironclads that followed, neither was vanquished. The *Merrimac* retired to Norfolk without having accomplished any part of her projected day's work, and the *Monitor* remained on guard, successful in the duty she had undertaken, and ready to fight the first comer.

In the fight the *Monitor* fired forty-one solid 11-inch round shot, twenty of which made marks that were afterward observed on the shield of the *Merrimac;* the iron plating of the latter was much disturbed and broken, but the casemate was nowhere pierced all the way through. Twenty-one of the *Merrimac's* shells (she fired no solid shot) struck the *Monitor*, the most damaging blow being one that cracked an iron "log" of the pilot house and disabled Lieutenant Worden. Two men in the turret were disabled by concussion. No one was killed on the *Monitor*.

As the first conflict between mastless steamers,—engineers' ships,—it will be interesting to remark briefly the part taken by men of the engineering force. The crew of the *Monitor*, including Chief Engineer Stimers, numbered fifty-eight. Of these, thirteen were officers. Five officers were of the line, or seaman branch; five were engineers; the others were the surgeon, paymaster, and captain's clerk. Twenty-one enlisted men were petty officers, seamen, and landsmen of the seaman class; seventeen were firemen and others belonging to the engineer class. The remaining seven were yeomen, stewards and cooks. It appears that the fighting force,—the men at the guns, in the magazine, and

BY KIND PERMISSION OF MESSRS. WARREN & CO., PITTSBURGH.

CHIEF ENGINEER ALBAN C. STIMERS, U. S. N.



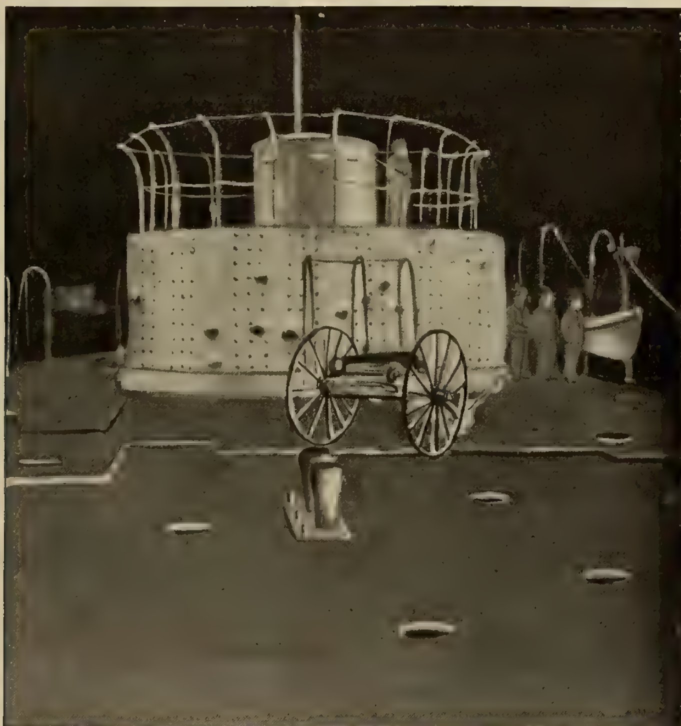
A VERTICAL SECTION OF THE "MONITOR'S" TURRET, SHOWING THE PENDULUM SCREENS FOR THE GUN PORTS. FROM A HITHERTO UNPUBLISHED ORIGINAL DRAWING BELONGING TO PROFESSOR C. W. MAC CORD.

at the engines and boilers supplying power to handle the ship and the guns, were almost equally divided between the seamen and engineering branches.

The familiarity of Chief Engineer Stimers with the various mechanisms in the ship enabled him to take a leading part in the battle. Indeed, it is not too much to say that without his knowledge the *Monitor*, in all probability, could not have gone into action at all, a point that is made by more than one historian. The exigencies of the trip from New York had prevented cleaning and oiling the turret-turning gear, resulting in its rusting, and it worked badly in the engagement. Colonel Church, Ericsson's biographer, says:—"But for the energy and determination of Engineer Stimers it might not have worked at all."

The station of Mr. Stimers during the fight was in the turret, working the turning gear. This station was originally assigned to one of the line officers, but he could not manage it, as afterwards stated by the executive officer, Lieutenant Greene, and was relieved by Stimers. When Worden was disabled and Greene took his place in the pilot house, Stimers relieved the latter in command of the turret and the last guns of the engagement, fired as the *Merrimac* withdrew, were fired by him. The New York Chamber of Commerce gave Ericsson a banquet in celebration of the battle, and in making his speech on that occasion Ericsson asserted that the success of the *Monitor* was "entirely owing to the presence of a master-mind," meaning Mr. Stimers.

Important as were the services of Chief Engineer Stimers in this stirring event, they were not greater than those of the officers and men of the engineer branch of the crew. In this, as in any engagement of a war steamer, power is



THE "MONITOR'S" TURRET, SHOWING MARKS OF SHOT. REPRODUCED FROM A PHOTOGRAPH TAKEN SHORTLY AFTER THE BATTLE.

the prime essential for manœuvring the ship and working her turrets, and the men who furnish that power contribute quite as much to the result as do those who use it.

The *Monitor* was doomed to a short existence. After the fight she remained at Hampton Roads in anticipation of another raid by the *Merrimac*, engaging once the batteries on Sewall's Point. On May 12 she led the squadron of vessels that went to Norfolk on the evacuation of that place by the enemy. Three days later, with the *Galena* and three other vessels, she went up the James river to within seven miles of Richmond and attacked Fort Darling, on Drury's Bluff. Owing to difficulty in elevating her guns enough to bear on the fort, her part in the attack was insignificant: she was struck three times and had no casualties. The *Galena*, another product of the armour-clad board, it will be remembered, was roughly used by the plunging shot from the bluff. Her captain, the gallant John Rodgers, remarked in his report:—" We demonstrated that she is not shot proof." Her bar armour was shot through thirteen times; thirteen of her men were killed and eleven were wounded.

During the summer months the *Monitor* remained in the James river on patrol duty, often engaged with the enemy's sharpshooters and shore batteries. At the end of the year the Navy Department began assembling a fleet of iron-clads off Charleston for the reduction of that place. The *Monitor* and a new and improved monitor—the *Passaic*—left Hampton Roads on December 29, under tow, but using their own engines. The next night, off Cape Hatteras, heavy weather was encountered and the *Monitor* foundered. Water in quantities came in under the turret and through the hawse pipes, and the experiences of her first sea trip were generally renewed.

The water gained steadily and impaired the fires by swashing against the grate bars, until the falling steam pressure showed too plainly that the engines and pumps must soon stop. At 10.30 P. M. signals of distress were made to the vessel towing her —the *Rhode Island* —and that vessel undertook the dangerous and very difficult task of removing the crew by means of boats in the heavy sea, but before the work was done the *Monitor* sank. This happened soon after midnight in the morning of December 31, 1862, about twenty miles south-south-west of Cape Hatteras. With her perished Acting Ensigns Norman Atwater and George Frederickson; Third Assistant Engineers R. W. Hands and S. A. Lewis, and twelve enlisted men. In Commander Bankhead's report of the disaster he asserted his conviction that a serious leak had been sprung by the pounding of the sea, separating the iron hull from the upper body, and this seems very probable.

THE LIVERPOOL OVERHEAD RAILWAY AND DOCKS.

By S. B. Cottrell, M. Inst. C. E.

THE Liverpool Docks, justly accounted one of the wonders of modern commerce, extend along the Mersey a distance of six and a half miles. They afford a spectacle unrivalled in the world, and leave upon the visitor a lasting impression of what the commercial and maritime supremacy of Great Britain really means. Nowhere else can there be found crowded together a succession of sights of such varied interest and activity. The great ports London, New York, Hamburg and Antwerp, possess, each in its way, the fascination which attaches to scenes of concentrated activity and the picturesque attractiveness of crowded waterways and masses of shipping; but the great port of the English manufacturing North and Midlands stands in many respects absolutely without a compeer, not merely because of its noble river, whose tidal movement is four times the outfall of the Mississippi, but because its dock system is, in point of extent and importance, indisputably the first in the world. This arises, to a great extent, from the character of the Liverpool trade.

Measured by the values of exports and imports the trade of Liverpool and London are about on a par, each figuring up to about £200,000,000 a year; but judged by bulk, the merchandise dealt with on the quays at Liverpool is vastly greater in value than that dealt with at Blackwall and London Docks, for cotton and grain, timber and tobacco, textiles and machinery are, bulk for bulk, of much less value than tea, silks, and French wines, or even articles "made in Germany." To gain an idea of the great currents of trade with North and South America, the West Indies, the Mediterranean, West Africa, India, China and the East, which are concentrated at Liverpool, a visit to the Liverpool Docks is absolutely necessary, and is an experience at once interesting and profitable.

The construction of the Liverpool Overhead Railway has rendered such a visit pleasant, expeditious, and easy. Until the railway was built in 1889, the only means of locomotion along the line of docks was by broad-wheeled omnibuses, which were specially built to run on the low-level dock railway, and were slow and cumbrous. Moreover, the 'buses were constantly brought to a standstill in a vortex of traffic, or shunted to make a passage for trains of goods waggons, for whose use the low-level dock railways were constructed, and for which they are now entirely reserved. Besides its delays, the 'bus journey, as experience proved, had its dangers; and it generally occupied an hour and a quarter in covering the seven miles of route.

The manifest inadequacy of such a mode of locomotion for the needs of the public led to a proposal for a high-level passenger railway as long ago as 1852. It was not, however, until 1882 that the Dock Board obtained the Parliamentary powers to construct the line. In 1888 these powers were taken over by the Liverpool Overhead Railway Company, who pushed forward with the work without delay, since by that time the practical impossibility of conducting both goods and passenger traffic on the same level had been fully demonstrated. That the Overhead Railway met a great want is proved by the fact that while the old 'bus service sufficed for about two

THE ENTRANCE TO CLARENCE DOCK.

and a half million passengers per annum, the traffic on the Overhead is now nearly nine millions, and is steadily increasing.

By recent extensions north and south the railway has been brought into contact with the important residential suburbs of Seaforth and Waterloo at the north, and Prince's and Sefton Parks at the south ends of Liverpool, and connects them with the centre of the city and with each other. Previously "greater Liverpool" had no direct means of public locomotion from end to end, and it took longer to cross the intervening seven miles of city than to travel to Manchester. It may be noted also, that while the railway was made overhead as a matter of necessity, its construction on that principle has proved a great boon, rendering journeys along the docks, whether on business or pleasure, agreeable and airy; for while the passenger inhales the stimulating ozone, he enjoys an unrivalled panorama of the majestic river, and of the greatest aggregation of shipping in the world.

The view which meets the eye of the visitor who has mounted to the Pierhead Station at the foot of Water street, extends across the Mersey, having for its background the docks at Birkenhead, and in the farther distance Bidston Hill, with its woods and observatory. In the intervening space appears the river, a busy highway for craft of all sorts, sizes and nations, where, on most days, the giant liners prepare to embark passengers. The foreground of the picture is filled in by the crowded and bustling landing stages, now close upon a mile in length. Lying alongside them, almost always, is a picturesque confusion of ferryboats, tugs, and channel steamers, whose variously coloured funnels and whose snorting steam signals add to a scene of rare animation, while immediately below, where the visitor is standing, extends the open space of the pierhead, crowded with cabs, omnibuses, tramcars and pedestrians in constant movement. Coupled with the ever-changing aspect of the Mersey, at one time shining in bright sunlight, at another grand and stormy, but always beautiful, scenes like this have a stimulus even for those who have lived among them a lifetime.

Travelling northward from the Pierhead, the train passes the Prince's Dock, now occupied by the Belfast trade, affording another interesting vista of the river across the Prince's Half-tide Dock, which is connected with the Prince's by the large swing bridge of

modern construction, built to carry the passenger railway from London to Riverside Station. The landing of cattle by hydraulic lifts at the Prince's jetty is observable from this point, whenever —as frequently happens—an Irish or Scotch steamer is alongside. Passing the Prince's Half-tide Dock, the train runs close by the Waterloo Dock warehouses, which are one of the sights of the port. Conspicuous across the river appear at the same time the great grain warehouses at Birkenhead.

Liverpool is the greatest grain emporium in Europe, and in these and other structures are kept the stocks of wheat usually sufficient to last the country from three to four months. The graceful three and four-masted sailing-ships which make the voyage from San Francisco around Cape Horn, as a rule discharge in the Waterloo Dock. On the city side of the railway at this point is situated the Waterloo Goods Depôt of the London and North-Western Railway, covering an area of some ten acres. North of the Waterloo are the Victoria, Trafalgar, and Clarence Docks, which have been for a number of years occupied by the trade with Glasgow, Dublin, Cork, Bristol, London and other ports. These docks were built in the forties. The sheds, being lower than the railway, allow of an interesting view of the busy coasting traffic with which these docks are occupied, and of their crowded quays and multifarious shipping. The Clarence Graving Docks, too, always present a picturesque spectacle of vessels in process of overhauling.

On re-starting from the Clarence Station the train crosses the two-decked spring bridge constructed to admit of the entrance of ships into the Stanley Dock—the only dock on the east, or town side, of the railway. The lower "deck" of this bridge forms the ordinary roadway, and can be worked by

PIER HEAD STATION OF THE LIVERPOOL OVERHEAD RAILWAY.

THE ENTRANCE TO PRINCE'S DOCK.

means of bascules independently of the upper, a passage being thus allowed for smaller craft without interrupting the railway communication. From the bridge a visitor has one of the best views of his journey. On the one hand he looks over the Collingwood Dock, occupied by the trade with Havre, and other ports with—beyond it—the Salisbury Dock, and in the background the Mersey; while on the other is situated the Stanley Dock, with its groups of large sailing vessels, and immense warehouses stored with cotton and tobacco. The extensive and recently constructed "Wool Floor," the centre of the American and East Indian wool trades, adjoins the Stanley Dock.

Passing the Nelson Dock, the railway, when abreast of the Bramley-Moore, dips down to ground level in order to clear the L. and Y. Overhead Siding which communicates with the Bramley-Moore and Wellington Dock coal tips, these docks being chiefly appropriated by the coal trade. Passengers, however, are scarcely conscious of this change of level. Another pleasing view is now afforded of the steamers under treatment in the six Sandon Graving Docks, which lie parallel with the railway Afterwards we pass the Huskisson Dock, occupied by the large vessels of the Leyland, Lamport and Holt, and other lines; also the recently constructed Canada Branch where berths are found for the *Campania*, *Teutonic*, and other giants of the Cunard and White Star Companies. From this point northward the railway passes the acres of timber stacked in the yards of importers at the Canada and Brocklebank Docks. The timber quays are one of the sights of the port, for the timber trade of Liverpool is immense, and there has been difficulty in finding room for it.

A CANTILEVER BRIDGE ALONG THE LINE OF THE OVERHEAD.

Finally, after a run of over three miles, we arrive at the great steam docks occupied by the Atlantic trade. These docks are enormous, and the visitor who does not mind moving about among loaded lurries, and can keep out of the way of trucks, will be well repaid by devoting some time to their inspection, for there liners may be seen surrounded by hosts of coaling craft, and the operations of stowing, landing, and distributing cargo are carried out on the largest scale and in accordance with the most modern methods. The terminus at Seaforth gives access to the fine stretch of sands extending to Waterloo and Crosby, and the railway has in

THE OPENING CEREMONY OF THE FIRST TRAIN ON THE LIVERPOOL OVERHEAD RAILWAY, SHOWING SIR DOUGLAS FOX, AND THE LATE MR. J. H. GREATHEAD, ENGINEERS; SIR W. B. FORWOOD, CHAIRMAN; AND MR. S. B. COTTRELL, MANAGER.

many respects enabled Seaforth, as a popular seaside resort, to rival New Brighton.

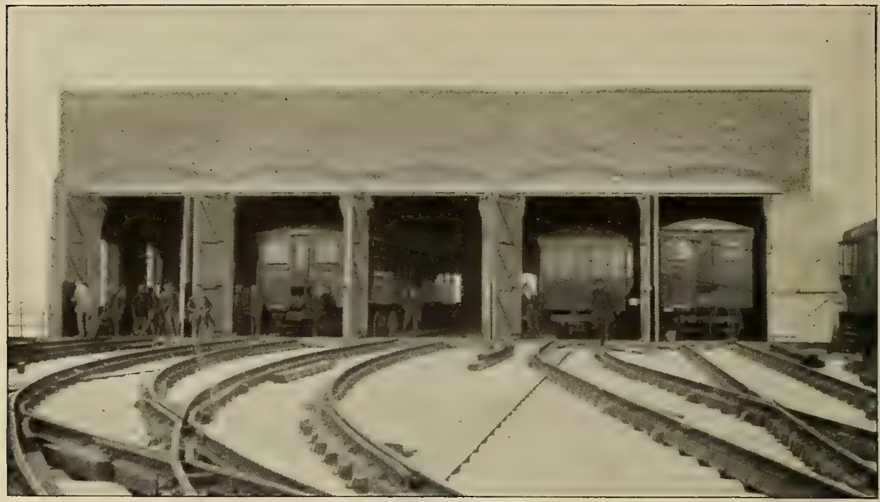
From the Pierhead southward the train first passes the George's, the oldest existing dock. It is generally filled with sailing vessels and coasting craft, though part of the west side has lately been appropriated for a portion of the Belfast trade. At the foot of James street is the remarkable building, nine stories high, completed not long ago as an office for the White Star Line. Separated from the George's Dock by Mann Island, a remnant of Old Liverpool, is the Canning, with its system of graving docks beyond. Another view of Birkenhead, with its docks and shipyards is afforded here, while on the Liverpool side loom the immense mass of the Albert Warehouses; and on the city side of the railway is the great pile of buildings which contain the Custom House, General Post-Office, and Dock Offices. These buildings, crowned by a lofty dome, were erected on the site of the Old Dock, which was filled up for the purpose in 1819, though the massive dock walls still remain buried in the ground. Here at one time flowed the "Pool" from which the city takes its name, a tidal inlet of the river that extended along what is now Paradise street, Whitechapel and the Old Haymarket. The pool was the ancient port of Liverpool.

In this connection it is interesting to note that all the creeks or inlets of the river are styled "pools," Wallasea Pool, Bromboro' Pool, and Otterspool being other instances of this nomenclature. The largest of these, Wallasea Pool, covered about 130 acres, of which nearly 100 acres have been formed into the Great Float, the largest dock in existence. South of the Canning lies the Salthouse Dock, largely used by grain ships. The Albert Dock is between Salthouse Dock and the river. For some distance along this portion of the estate there is a double line of docks, the next group being the Wapping,

King's and Wapping Basin, with, between them and the Salthouse and Albert, the Duke's Dock, now the property of the Manchester Ship Canal Company, and the centre of the inland traffic via the Bridgewater Navigation. On the west side of the King's Dock are the extensive King's Dock Tobacco Warehouses, and alongside Wapping Dock the lofty Wapping Dock Warehouses. Much spectacular interest attaches to this part of the trip on the Overhead Railway, since these docks are wholly occupied by large sailing ships, whose lofty tapering spars rise above the roofs of the highest warehouses. To the south of the Wapping Dock extends the Queen's, one of the largest docks on the estate, and within the last few years brought into line with the latest requirements as a deep-water dock by the system of pumping, designed by the predecessor of the present dock engineer, Mr. G. F. Lyster. The Queen's Dock is now used by steamers of very large tonnage. To the west, between the docks and the river, is a range of shipbuilding yards, and although shipbuilding has not been a flourishing industry on the Liverpool side for a good many years past, a number of vessels of moderate tonnage are still turned out.

Immediately, however, the train passes the Queen's, a fine view opens up over the whole length of the Coburg Dock, which lies at right angles with the river and the railway. The Coburg, the centre of the African trade, is one of the busiest docks of the port, and is almost always crowded with fine mail steamers discharging African produce, or shipping textiles and other goods for the west coast of Africa. The Brunswick, with its shipyards beyond, and its range of graving docks adjoining, is another great basin, in which are berthed the steamers of the Booth Line, trading to the Brazils, and other important lines. From this point southwards the docks, including the Harrington and Toxteth, are largely occupied by the great trade with the East Indies and South America. The traffic with the River Platte is, therefore, centered here, but during the cotton import season the south docks are also crowded by cotton steamers from New Orleans,

A VIEW OF THE LINE AND ELECTRIC CONDUCTORS.

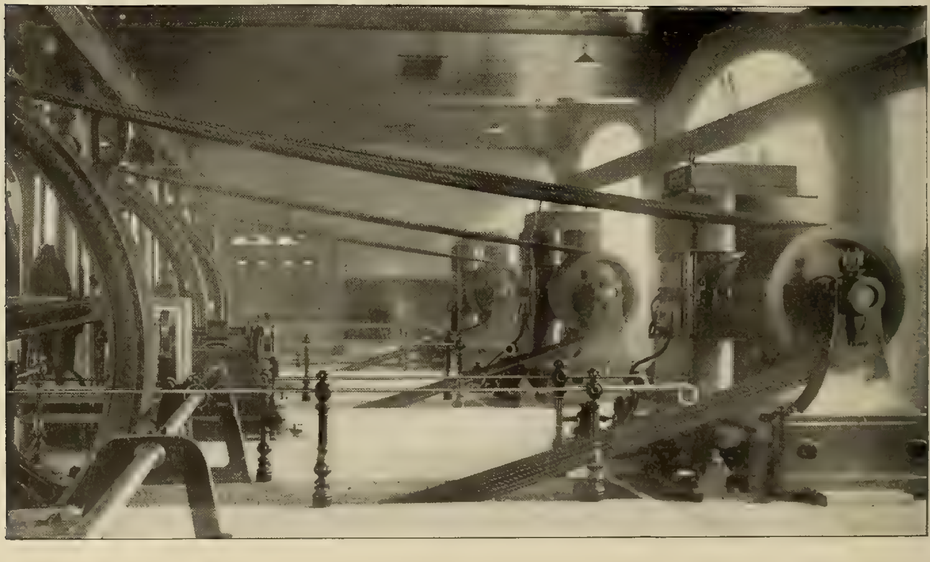


THE CARRIAGE DEPOT.

Galveston, and Mobile, and large vessels may then be seen lying alongside the quays as many as six deep.

More recently pressure of traffic has caused the transfer of a portion of the cotton trade to the Hornby Dock, at the extreme north. The sheds of these south docks are of the two-story type, doubling the facilities for discharge, and in busy seasons the masses of merchandise which may be observed in process of handling are enormous. At the far south of the estate the Herculaneum Dock is occupied largely by the tank oil trade. The cliffs here rise to a considerable height above the quays; but the rock has been hollowed out for the construction of extensive stores for the storage of petroleum in bulk.

The foregoing description is but a rapid and cursory survey of the many sights of interest which render travelling



THE ELECTRIC GENERATOR ROOM.

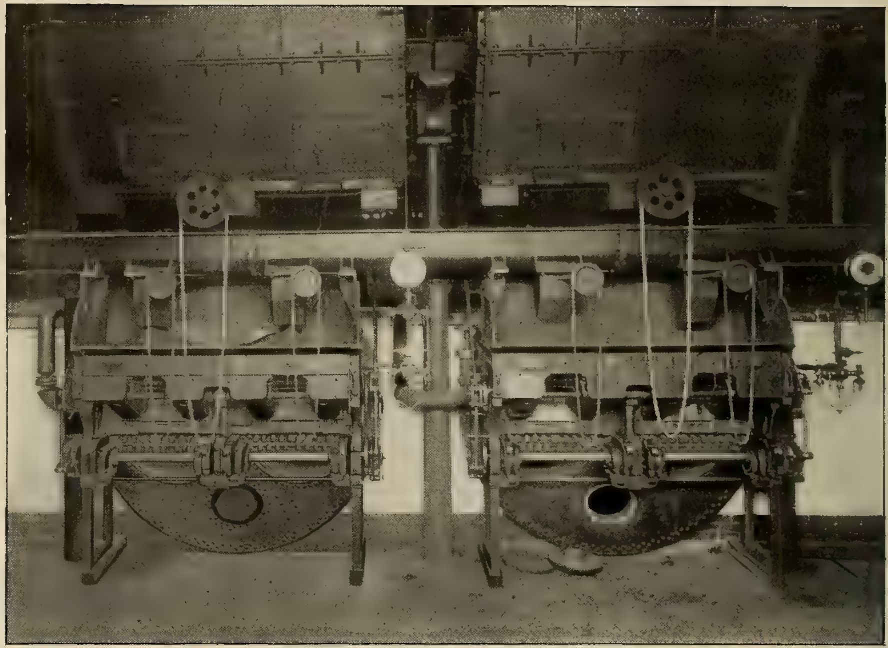
on the Overhead Railway a valuable experience as well as a pleasure. If the visitor starts from the Pierhead Station he will, by going north, then south, and back again—traverse the whole length of the line twice over, but on each journey he has the advantage of different points of view, which invest what he has already seen with the fresh interest of an altogether new impression.

The original estimated cost of the Overhead Railway was £585,000, but this was subsequently reduced to £466,-

ONE OF THE STATIONS.

000 for a system worked by electricity. The works were designed by Sir Douglas Fox, M. Inst. C. E., and the late Mr. J. H. Greathead, M. Inst. C. E., and carried out under their supervision by Mr. Francis Fox, M. Inst. C. E., and the writer, who, on completion of the works, was appointed general manager and engineer in chief to the company. The construction decided on was wrought-iron girders, placed 22 feet centre to centre, with a normal span of 50 feet, and elevated to a height of 16 feet above the roadway by columns built of two steel channels and two plates. These columns are grouted into cast-iron shoes, held down by bolts to concrete foundations, the size of which varies according to the nature of the ground, the weight being distributed at one ton to the square foot. The bottoms of the columns are protected against injury from passing waggons by cast-iron bumpers.

To admit of the free access of traffic to and from the Pierhead, the railway is carried across that space by bowstring girders of 98 feet span. Between the girders, which form the foundation of the permanent way, is placed a continuous flooring made of arch plates 5-16 inch in thickness, bent to a radius of 12 inches, with a surface 16 inches wide at the top. This flooring is made watertight by means of channels between the arches, drained by outlets into longitudinal gutters which discharge



A SET OF BOILERS IN THE POWER STATION.

into down spouts fixed on the columns. The watertight structure of the flooring was one of the obligations imposed on the company. The flooring combines great strength with lightness and a minimum of rivetting, while it is at the same time comparatively noiseless under traffic,—an important matter considering the great amount of horse traffic on the ground level.

The structure was so designed that after the erection of the first few spans the girders and flooring were put together and rivetted, transported over the completed part of the structure and placed into position without interfering with traffic. In this way the railway was built with practically no interruption of the low-level communication. To accomplish this, a special form of erecting apparatus was used, consisting of lattice girders, the front pair of which travelled on the ground, while the hind pair travelled on the viaduct already built. On these lattice girders suitable cranes were erected, so that the completed span could be launched forward into position. In this way as many as twelve spans, of from 50 to 70 feet each, were fixed in 5½ working days, representing 650 feet of finished viaduct. At four different places on the line, opening bridges had to be provided. The hydraulic swing bridge at the Stanley Dock has been already referred to. At the three other points bascule bridges, worked by hydraulic power, are provided, to admit of the passage of boilers, and other objects, too high to go under the main girders. The permanent way, laid to a gauge of 4 feet 8½ inches, consists of flat-bottomed steel rails, weighing 56 pounds per yard, fixed on longitudinal sleepers, held down by lugs, rivetted on to the flooring and keyed with oak keys.

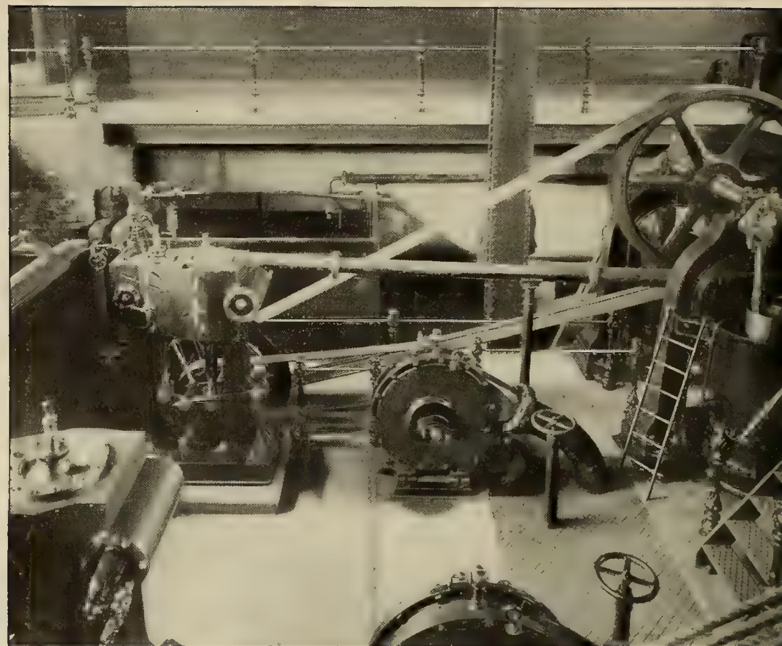
As originally carried out, the viaduct was the length of the line of docks, but in 1894 the Liverpool Overhead Railway Company completed the extension of the line to Seaforth. This northern extension was one quarter of a mile in length, but opened up another three-quarters of a mile for traffic. That its construction was fully justified was shown by an immediate increase of

traffic exceeding 2½ millions of passengers per annum. The southern extension from the Harrington Dock to the Dingle terminus in Park Road was completed and opened for traffic during the present year. This extension is five-eighths of a mile long. It begins 150 yards north of the terminus at the Herculaneum Dock, and, crossing a viaduct 250 yards long, which spans Sefton street, the Brunswick Goods Yard of the Cheshire Lines Railway and a portion of the Dock estate, enters the hill at the northeast corner of the Herculaneum Dock and proceeds in a southeasterly direction to Park Road. The Dock Board required that their land should be crossed by one span of 200 feet, and to accomplish this the line is supported on main girders of the lattice type with parallel booms. These girders are 220 and 225 feet long, respectively. The weight of the whole of the span is about 212 tons.

The cliff at the Herculaneum Dock mentioned above has been hollowed for the storage of petroleum. These petroleum casements extend about 60 feet into the hill. To distribute the weight of the big girder over them, it was found necessary to rest the east end of the span upon a bearing girder weighing 10 tons, which was let into the rock where the main girders rest at the face of the tunnel. The west end of the span rests on a pier provided with rollers and rockers. The normal tunnel, 800 yards long, giving access to Park Road, has a span of 26 feet from springing to springing, and 25 feet 6 inches between side walls. The arch is semi-circular. The tunnel for the station is 52 feet span, with a segmental arch having a quarter span rise. To construct the tunnel, five shafts, 10 feet square, were sunk, from the bottom of which headings, 11 feet and 12 feet, were driven in each direction. The greatest error in line and level was under three-quarters of an inch.

A CAR INTERIOR ON THE OVERHEAD.

The tunnel is driven almost entirely through red sandstone rock. Its construction was difficult, not only on account of the treacherous character of the



THE CONDENSER ROOM IN THE POWER STATION.

red sandstone rock through which it had to be driven, but because about 170 feet from the entrance it crosses, at an acute angle, the tunnel of the Cheshire Lines Railway, and the greatest distance that could be allowed between the Overhead rails and the crossing of the Cheshire Lines Tunnel is 2 feet 9 inches. The crossing was, however, safely accomplished by turning over the lower tunnel a segmental screen arch, five rings thick, leaving a clear of 6 inches over the Cheshire Lines space arch, and so securing it from additional weight from above. Provision had also to be made for the future construction of a second tunnel by the Cheshire Lines Committee, parallel to that now existing. To obviate interference with future traffic the Overhead Railway Company decided to build on the lower level a length of tunnel arch, seven rings thick, on which the side walls of the Overhead Tunnel were carried. Further on, the tunnel passes beneath a main town sewer, which by alteration of the arch from semi-circular to segmental, was, with care, successfully underpinned.

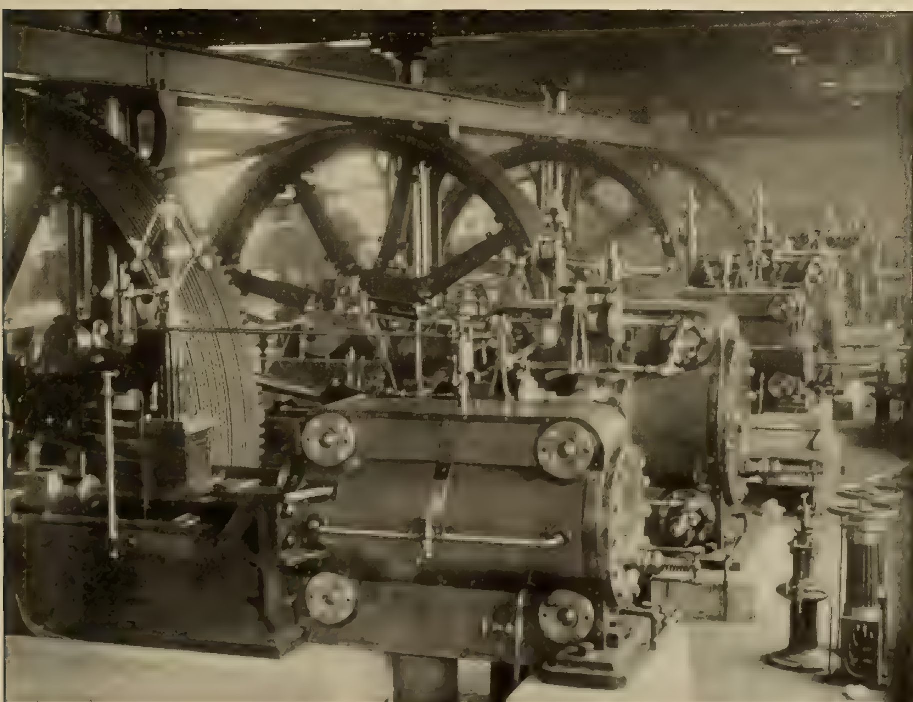
The adoption of electricity as a mode of traction for the Overhead Railway was resolved upon after careful consideration. For some time after the opening of the line the trains consisted of two carriages, each 45 feet long and 8 feet 6 inches wide, running on two bogies, 32 feet apart, from centre pin to centre pin, with 2-foot 9-inch wheels. Each carriage contained seating accommodation for 16 first-class and 42 second-class passengers. To meet the demands of increasing traffic the trains are now composed of three carriages. Each carriage is fitted with an electric motor, and the train is controlled by a driver from either end, thus avoiding all shunting at terminal stations. The armatures for the motors are series wound and built directly on the axle. The tractive force of each motor at rim of wheel, with 120 amperes, is 1790 pounds — equal to about 107 pounds per ton of train.

The trains pick up the electric current from a conductor laid in 32-foot

lengths, connected with rigid copper fish plates, with flexible joints every 96 feet. It is supported on insulators which are carried on cross timbers between the two running rails, which are used for the return circuit, and, in addition to fish plates, are coupled together with a bent wrought-iron bar. The trains are fitted with the Westinghouse automatic brake, supplied with compressed air at 80 pounds pressure from reservoirs at the terminal stations. A train of three coaches, fully loaded, weighs 57 tons, of which the motor equipment is 9 tons 10½ cwt.

The power is supplied from the generating station at the Bramley-Moore Dock. To meet increase of traffic, the equipment has recently been increased 50 per cent. The first equipment consisted of six double-flue Lancashire boilers, 30 feet long by 8 feet diameter, and of four horizontal compound condensing engines built by Messrs. Musgrave & Sons, Limited, of Bolton. Each engine develops 400 I. H. P. The condensing plant is in duplicate. Each engine drives an Elwell-Parker dynamo, 500 amperes, 400 volts. The efficiency of the dynamos and engines is 85 per cent. at full load. The current from the dynamos is controlled by a switchboard equipped with cut-outs and working automatically in case of a short circuit. By means of this the current is conveyed to the centre conductor on the railway and picked up by collectors of cast-iron fixed underneath the trains.

The addition to the outfit of the generating station consists of two new dynamos and switchboard by Messrs. T. Parker & Co., of Wolverhampton, and two engines, by Hick, Hargreaves & Co., of Bolton, of the horizontal surface condensing type, each intended to give 400 I. H. P. as an economical load when running at 100 revolutions per minute with a boiler pressure of 120 pounds. The engines are of ample proportions throughout, fitted with flywheels 14 feet in diameter, each wheel being grooved for nineteen 1¼-inch



A VIEW OF THE ENGINE ROOM.

diameter ropes. The cylinders are of the four-valve Corliss type, built of four principal castings. This both reduces the chance of disablement and enables a defective part to be replaced with much less expense and delay than if the cylinders were, as usual, cast in one piece. The governors are of new design, specially intended to combine power with great sensitiveness for dealing with marked variations of load. The output of each dynamo is 500 volts 500 amperes. The total weight of each dynamo is 24½ tons. At the north end of the line the company have fully equipped workshops at which they carry out their own repairs.

The carriages are lighted by 32-candle power incandescent lamps supplied from the main conductor. On entering the tunnel at the south end of the line the trains are automatically lighted from copper conductors suspended from the roof of the tunnel, collectors being fixed on the roofs of the carriages. The station at Park Road is below the surface level. The access is by a subway with a gradient of 1 in 14. It is lighted by electricity, and the arrangements for ventilation and sanitation are of the most improved and perfect character.

The cost of maintenance of the line is naturally very heavy, as there are over 80 acres of surface to be protected from corrosion, of which 20 acres are painted with an oxide paint and remainder with black varnish, and at the present it is being painted about once in two years. Experiments have been made with a pneumatic painting machine, which blows the paint on, the result being to reduce the cost from 2.25d. per square yard to 1.24d. per square yard, including all materials.

The motors now run an average of 40,000 miles before requiring repairs, in which time they earn over £200 and can be rewound at a cost of £25.

TRADE UNIONS AND POLITICAL ECONOMY.

By Francis G. Burton.

AN important lesson of the recently ended engineering struggle in Great Britain may possibly be lost sight of in the glamour of the angry passions and immediate issues involved, unless special attention be directed to it by the press. The newspapers, more especially the Radical papers, urged the British Board of Trade to take action to bring about a conference between the two belligerents on the ground that they really did not understand each other's position, and were divided by mere phrases and interpretation of words (barring the eight hours - question) rather than by any essential differences of view as to management and control of workshops.

The lesson taught by the conference and continued struggle is, however, a much deeper one than this; it is, that the working engineers and their leaders are unable to grasp the significance of the language in which their employers address them, or the force of the arguments employed to resist their demands. So far as understanding is concerned, the masters might just as well have addressed the delegates in Sanscrit or ancient Greek; the words employed by them conveyed a different meaning to their hearers than they intended, and even roused "an enemy in the gate" (as Mr. George N. Barnes expressed it), when they were really intended to be conciliatory.

The reason is not difficult to arrive at, if we consider the evolution of trade unions and their leaders. When the unions were first formed, British workmen were scholastically uneducated, and few of them were able to read or write; of the few who could do so, a still more limited number had access to any books of standard worth. Even the employers of half a century ago had frequently received far inferior education to that now obtained by a seventh-standard boy in a board school. The masters were often oppressive, and sometimes brutal; wages were paid irregularly, and partly by orders on the truck shop; and the rulers of the country had no higher view of good government than the suppression of riot and anarchy.

From such uncouth materials as these workmen arose the earlier unions; from the more impulsive and desperate of them were selected the leaders. The creed which they adopted was, of necessity, a narrow one. They saw despotic masters, and opposed oppression by strikes and brutality; they beheld accumulating wealth, and answered it by increased loyalty to their unions. Loyalty to the union of their trade became, indeed, a fetich with them, and not intelligent fidelity or necessary combination.

The conditions are now altogether changed. The masters are more altruistic, and the workmen both can, and do, read and write; but the fetich remains, and the men and their leaders imagine they have still to struggle against "unreasoning assertion of dominance and lawless independence" on the part of employers. With such a creed dominating the work people, it is but natural that the greatest demagogue, the most blatant orator, should guide and rule them rather than the calm and

thoughtful reasoner, who can see some good in both sides of the question.

The truth is, the men hear only one side, and read only newspapers which confirm their own views, and urge them to persist in their claims and in obstinate opposition to their employers. The fault is not entirely with the men. In the evolution of society a stronger line of demarcation than of old has grown up between master and man; the old feudal tie of service and protection, with its mutual respect and sympathy, has been exchanged for the commercial idea of free contract, and purchase in the cheapest market. A change like this, especially when combined with increased intelligence and education among the working classes, demanded great watchfulness on the part of the capitalists, and some method of communication between the two, some mode of keeping touch, when the old familiar lines had become obliterated. Had this been done, wisely and courteously, the general body of workmen would have gained a knowledge of the discoveries and conclusions of statistical and economic science. As it is, they know little of the work of the economists, except such distorted presentments as they obtain from socialist newspapers or socialist orators.

Recently I received a letter from a member of the Amalgamated Society of Engineers, an engineer working at his trade, but more thoughtful and widely read than most of his class, in which the following passages occur:—

"I, like yourself, prefer Stuart Mill to Tom Mann; only the worst of it is that where the former has one student, the latter has thousands. It has often struck me that it would pay the masters of Great Britain to have itinerant lecturers in their employment, to follow these rabid socialists about the country to attend lectures and other meetings, and oppose the many wild statements put forth by these firebrands. I am sure that such a system, if adopted, and reputable men, of acknowledged ability and moral character, were selected for such a purpose, these mouthy orators would find it very difficult to find sympathetic audiences.

"Recently, I heard both Mann and Burns, and I felt, whilst listening to them, what poor, weak, wishy-washy twaddle they were talking. But it all went down as being the purest gospel. In short, the average working man will not think, and these agitators play down to the meanest instincts in human nature, and so they have got a hold upon the trades unionists of this country.

"The average working man, in a way, has a noble side to his nature, and also a desire to know the truths about things in general; but being the poor frail creatures that we are, we do like having our little vanities tickled, and our half-baked ideas of political questions congealed into concrete form which square with the apparent well being of our order.

"Stuart Mill is caviare to the general mass; so is Adam Smith, and so are all the political economists of the strictly orthodox kind. 'Merrie England' is written down to 'John Smith's' capacity, and so 'John Smith' understands it, or at any rate he reads it, and when he goes to his trade union he votes in accordance with it, and so we have war and chaos, with the attendant train of misery, want, and suffering. Give 'John Smith' Stuart Mill in a popular form, sell it at a penny, send missionaries to every industrial centre, and let them talk, argue, and discuss, and in a few years seed sufficient would be sown to give us almost a new race of working men, who would not tolerate the self-seekers who now gain a hearing in their meetings."

Is not this letter, written by a member of a trade union, a severe indictment of past neglect and indifference on the part of employers and capitalists, and a partial explanation of the disorders from which we are now suffering?

The want of knowledge of economics leads working men into very real blunders; the neglect of discrimination between cause and effect leads them into demands which cannot be reasonably sustained, nor prudently conceded. At a meeting held at Lambeth Baths,

London, last January, Mr. George N. Barnes said:—

"So long as the ownership of factories, workshops, and machinery lasted, the only possible means by which industry could be carried on uninterruptedly was by the full recognition by the employers of the right of partnership of the workmen in their employ."

Now it is impossible to define the exact terms and conditions of this "right of partnership" which the secretary of the A. S. E. says must be admitted if labour troubles are to be avoided. There is no general law or custom by which it can be gauged, and the trades unionists have avoided placing any limitation on their interpretation of it; but we know that it comprises not only rates of wages and hours of work, but the more important matters of speed and quality of workmanship, of numbers of apprentices, and of class of labour to be employed on any particular portion of manufacture, or in the working of any particular machine. The recent machine question in Great Britain, the demarcation disputes between fitters and plumbers, engineers and boiler makers, joiners and shipwrights, and the apprentice regulations of the flint glass-makers' unions are sufficiently familiar to us to show that the workmen's expectations and demands are in no wise exaggerated in this statement of them.

But the very desire for admission of the right of partnership is sufficient indication that the work people, or their leaders, do not recognise what the demand involves. If it is to be a real partnership, and because of its reality increases their emoluments in prosperous times, and enables them to suggest, or even insist upon, measures which they deem conducive to such prosperity, then it is only equitable that they should share in the reduced earnings and losses of adverse times. But to this they will absolutely object If the employer is to bear all the risk and worry of trade, whilst hampered on the one hand by State regulations, and on the other by trade union interference, and shop stewards' remonstrances, it will, under modern conditions of competition, be impossible to maintain a business at its highest average of prosperity.

The great advantages of division of labour have been admitted by all economists from Adam Smith onwards; but this division demands supervision, arrangement, and careful adjustment of men to the work for which they are best adapted. How this supervision is to be carried out, under the duality of partnership claimed, has never been explained by the union leaders, nor does the problem appear easy of solution.

This, however, is but the fringe of the question. One of the most important contributions to modern economic science is Mr. W. H. Mallock's work on "Labour and the Popular Welfare." He points out the enormous increase in the wealth of Great Britain, and whilst admitting the forces and conditions productive of wealth to be those given by previous enquirers, viz., land, labour and capital, he substitutes the term "human exertion" for labour, and merges capital in land and human exertion as being the product of the two. He does not, however, merely substitute one term for another without grave and sufficient reason for the change. A further analysis sub-divides human exertion into two parts, labour (*i. e.*, muscular labour) and ability, or the faculty which directs labour to the production of wealth. A very careful consideration of the recent increase of wealth, of the nature of its composition, and of the causes which have contributed to it, lead him to a very startling conclusion:—

"The real fact, then, on which I am here insisting is that, whilst the immense majority of the population produce little more than one-third of the income, a body of men who are comparatively a mere handful, actually produce little less than two-thirds of it."

Indeed, Mr. Mallock ventures to allege even that, "it may thus be said with regard to the production of wealth generally, that it will be limited in proportion to the exceptionally skilled labour it requires, whilst it will be in-

creased in proportion to the exceptional ability that is applied to it."

The reasoning of Mr. Mallock will be more readily accepted in America than in Great Britain, for the inventive and administrative faculties, which are forms of ability, have been fostered there by favourable circumstances, and the character and temperament of the people. But even in Great Britain some of the deepest thinkers are beginning to acknowledge the fallacy of attributing to labour,—that is, muscular labour,—all production of, or increase in, wealth. The theories of the Austrian school, presented to English readers very lucidly by Dr. William Smart, professor of political economy at the University of Glasgow, have materially assisted the reconsideration of the question, and forced men to think that something more than manual labour is needful to confer value. Looking at the question from another point of view, he is equally destructive of the ordinary trade union and socialistic claim in the following passage:—

"The bitterest economic discovery a man ever makes is when it is practically demonstrated to him that labour does not produce value. In vain does he protest that he has worked hard and worked well, and that a fair day's work deserves a fair day's wage. Society answers inexorably:—'We have nothing to do with your work; let us see your product; if it pleases us, we shall pay you for it; if not—!' The man feels that he is ill used, but he cannot say why. The fact is that he has not realised the contract under which he works.

"Even in simple circumstances, when man digs his living out of the ground, he never produces value. He digs his living because it is valuable; he does not make it valuable by digging for it. But, being himself the consumer, and so the determinant of value, he knows where value is, and directs his labour to get it. Once, however, he has joined the great co-operation of workers, which is modern industry, he does not make for himself but for others. It is they that now determine the value of his work, for they are now the consumers and determinants of value; and, cruel as it sounds, he has no more claim for wage, if he produce that on which society puts no value, than the painter, who leaves off digging potatoes to spoil canvas, has a claim to get a wage from a society which does not appreciate bad art."

Both the hypotheses of Mr. Mallock and Dr. Smart deserve consideration by modern trade unionists. If we admit either the supremacy of ability, or the determination of value by the consumer, it becomes impossible, on strictly economic grounds, to justify the claim for a "living wage," or for a partnership in products to which they merely contribute by their labour whilst the essential element of value,—the anticipation of the demand, and conformity to it,—are contributed by the employer or his superintendents or managers. It may be possible to press it on ethical or humane grounds, but this is just what the workmen reject; they will not accept, or consider as a charity, that which they demand as an inalienable right of man.

There is another point on which trade unions are at war with political economy, with experience, and even with the actions of their own members when left to pursue their way unfettered by society regulations. The engineers have, during the recent dispute in Great Britain, been openly charged by the Employers' Federation with endeavouring to limit the output of work per man. It is unnecessary to sift the evidence on which the charge is made. Even if the employers failed to prove it to be true (and it is just one of the cases where satisfactory direct testimony is most difficult to obtain), we have ample evidence that it is in perfect accordance with the theories and economics of the unions generally. The Glassworkers' Union is a strict corporation which, so far, has contrived to control the masters, and drive a large proportion of the trade out of the country to Germany.

Mr. Eli Bloor, of Birmingham, a working-man magistrate, and ardent unionist, was kind enough to explain

the regulations of the society to M. Paul de Rousiers, when that gentleman was making his inquiries into "The Labour Question in Britain." We may, therefore, justly assume that nothing was set down in malice to the detriment of the union.

"To limit admittance to our body," he says, "we have made an agreement with the employers under which they are not allowed to have more than one apprentice for two shifts,—that is, 10 per cent. of the staff." And when asked for an explanation of so severe a rule, which has been, and is, energetically enforced, Mr. Bloor pointed out that the work was healthy, and they had a very low mortality, but added, "We were unwilling to continue to teach the trade to a swarm of people, to breed competitors for the future."

Like a woman's postscript, this latter sentence contains the gist of his meaning,—the men were determined to maintain an equilibrium between the demand for labour and the supply of it, and were enabled to enforce their rules on the masters through their monopoly of special skill.

"The glassworkers are highly skilled experts, men who cannot be replaced, whom the masters cannot afford to lose, and with whom they must keep on good terms, and consequently they have been able to form themselves into a close corporation, entrance into which they jealously prevent. Their success is due to the exceptional position they occupy in the labour market."

But this success has not brought about the equilibrium at which they aimed. Even Mr. Bloor, strong unionist though he is, was compelled to admit that whilst they could limit the supply of labour, they could not ensure orders, and he was ready with many excuses for this falling off in trade. Any one, however, acquainted with the glass business, could have told him that, in reality, it has left the country; that the men in limiting labour, and consequently production, have driven the orders abroad, and so killed the goose which laid the golden eggs.

In the cotton industry we have a still more forcible expression of trade union opinion that limitation of production can benefit the workman. It is not necessary to go back to the hand loom weavers' days, nor recall the great "10 per cent." strike. Two recent instances will show that the ideas of "limitation" which moved the Luddites to riot, still hold good with more peaceable and better educated workmen.

The years 1891 and 1892 were seasons of great depression in the Lancashire cotton trade. The excessive production of American cotton had reduced prices, and the conditions at length became so desperate that employers were forced to demand a reduction of 5 per cent. in wages. The men rejoined that the trade was suffering from over-production, and that the true remedy was to close the mills for one or two days a week for a couple of months. Rather than consent to the reduction, they left work. The strike was preceded by negotiations, conducted with admirable moderation on both sides. Indeed, the secretary of the Cotton Spinners' Federation is a man of exceptional ability, who, whilst resolutely serving the interests of his union, endeavours at all times to sooth and pacify angry feelings. I quote the operative's argument in his own words:—

"If we had accepted the employers' terms," said Mr. Maudsley, "over-production would have continued and prices would have gone on falling. Then there would have been a fresh reduction, and so on, till the minimum subsistence wage was reached."

The strike continued from November, 1892, to March, 1893,—twenty weeks,—without sufficiently exhausting stocks or raising prices to enable the old wages to be paid. The men eventually consented to a reduction of 7d. in the £.

The second instance is the demand of the Manchester master spinners last year for a reduction of 5 per cent. in wages, which was answered by the men in the same manner, with an offer of reduced time, but at the old rate of wages. In this case the men were engineered by their former leader, Mr. Maudsley, and

the employers eventually withdrew their demand, owing, it is said, to divisions in their own ranks.

It seems hardly necessary to point out that if British workmen and labour leaders were as fully acquainted with the development of production in foreign countries, in the textile industries, for instance, but also in the engineering, shipbuilding and other trades, as British manufacturers and merchants are, they would see the folly of endeavouring to control the market by restricting production in Great Britain alone.

John Stuart Mill says:—" Wages," meaning, of course, the general rate, " cannot rise but by an increase of the aggregate funds employed in hiring labourers, or a diminution in the number of the competitors for hire; nor fall, except either by a diminution of the funds devoted to paying labour, or by an increase in the number of labourers to be paid."

And yet British workingmen, by ignoring foreign competition, and by regarding only their own local conditions, are assisting in the very depletion of the wage fund, and so in eventually lowering their own wages; first, by opening the markets to the competition of foreign countries where lower wages are paid for the same class of, and in some cases equally efficient, labour; and second, by inducing capitalists to remove their capital (that is, the fund for payment of wages) abroad where more favourable conditions exist for its employment. The commercial history of the past few years teach two lessons most forcibly, namely, that all the markets are equally free to any nation which seeks them, unless closed by absolutely prohibitive tariffs; and that the mobility of capital has increased, and this mobility tends to equalise the wages funds of various countries. What money the manufacturers of *A* require but do not possess, they can, by furnishing reasonable security, readily and speedily obtain from the bankers of *B*.

We are not exaggerating the grave menace which foreign competition is to British trade; indeed, it would almost seem as if the boasted supremacy of the British workshop, even in pet industries of the land, were a thing of the past. Sir Edward J. Reed, in a letter to the London *Times*, recently related how he saw a shop full of new machinery at an engineering works on the Clyde, " American made," although it was such as is produced in Leeds; how he saw two very fine steel forgings, " made in Germany," which cost between £100 and £200 less than they would in Sheffield itself, the natural home of the steel industry; and how he found that a certain forging of very special design, which could be produced only out of the very best materials, and by the best workmen, was being " made in Germany " for a Thames firm, the pattern being sent from Germany.

In recent visits to the Continent and the United States he had opportunity to observe the equipment and character of the establishments which now threaten British trade. When he saw the shipyards and engineering works at Hamburg and Stettin, he, and other members of the Institution of Naval Architects, " began to wonder how we were to hold our own without some ameliorations and conditions of labour in favour of British employers."

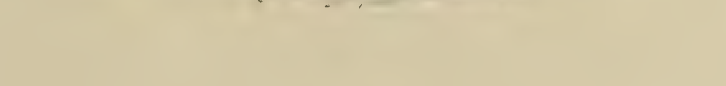
In New York he found capitalists and commercial men confident of speedily underselling British coalmasters, ironmasters, and engineers, both in foreign markets, and also in their native country. The anticipation appears to be justified by the perfection of the equipment, and the abundant use of labour-saving appliances in American factories; and he instances the Newport News Shipbuilding and Dry Dock Company's works at Newport News, in Virginia, which, he admits, he would find it hard to match in all respects on his own side the Atlantic.

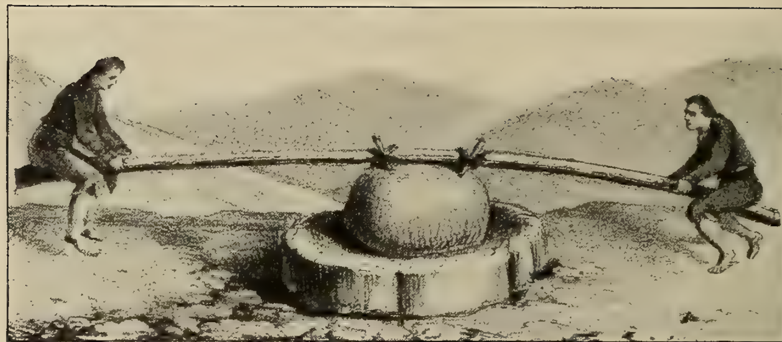
Even in France, which, by Englishmen generally, has been regarded rather as an agricultural than a great competing manufacturing country, he found that in many sections of engineering work British products were entirely falling out of the competition. He sees that the trade is leaving the country which he has himself served so well, and

though the employers must suffer, it is also "the working classes, and especially the humblest among them, who are being sacrificed wholesale, now and hereafter."

The warning from Sir Edward Reed is of especial interest, for, although he said he had no scheme of settlement to suggest (for the engineers' dispute), it is evident that he attributed much of the growing competition to the foolish and arbitrary conduct of the unions, and consequent restriction of output in British works. His words ought to carry great influence with the workmen; he is an eminent engineer, and is, therefore, well qualified to estimate the various complexities of the problem; but he is also a sincere and warm friend to the labourer, whether of high or low degree. No one who has had the honour to serve under him will easily forget the kind sympathy which he extends to those who strive to do their duty under adverse circumstances. If the unionists, in their blind obstinacy, will not listen to him, we may almost say of them, "Neither will they be persuaded, though one rose from the dead."

There is a moral from all this for the wealthy and educated men of Great Britain which they must take to heart if they will serve and save their country. The unions err through ignorance rather than from malice; but their organisation often renders them masters of the situation, and, in the scoffing words of Robert Lame, we must educate our masters. There is glorious opportunity here for talent, if wisely employed, but it must be used quickly or the chance will be altogether gone.





THE TRAPICHE, A PRIMITIVE FORM OF GRINDING MACHINE USED IN BOLIVIA.

CRUSHING AND PULVERISING MACHINES.

By James Douglas.

THE reduction of coarse particles to powder is an art to which the requirements of the most primitive as well as the most advanced man have always given prominence. Although the appliances with which this has been effected have grown in complexity and efficiency, as manual labour has been replaced by machinery, the same processes and principles are utilised in the operations that were, and are to-day, brought into play by the savage. His crude tools are the simplest expressions of our most powerful machinery. The stone hammer is the prototype of the steam stamp, and the two women, of old, grinding at the mill, were doing slowly what we do quickly with similar implements. The squaw, when crushing her corn in a stone metate, exerts the combined action of a breaker and a pair of rolls.

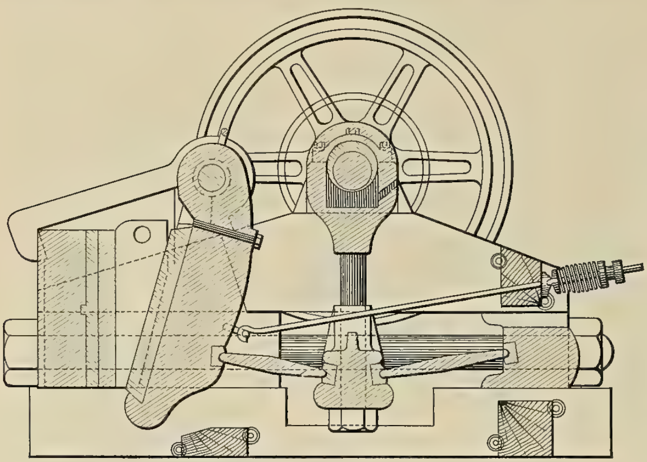
The savage recognises the fact that difference in material to be ground necessarily determines the form and kind of machine best fitted to do the work; but this elementary lesson some engineers are slow in learning. A mill, well adapted to grind cereals, may be most unsuitable for pulverising hard material. A treatise, therefore, on disintegrating machinery should describe separately the devices adapted for attacking each class of material. Obeying that rule, the following summary will be confined to crushing, grinding and pulverising machinery employed primarily in the reduction of rock to lumps, coarse grains, and powder.

In the United States more inventive progress has been made in the mechanical than in the chemical arts. Few great metallurgical processes have originated here, but, when adopted, they have been, through mechanical improvements, necessitated by local conditions, been worked up to such a degree of utility and productiveness, as to entitle the adaptation often to rank almost as an invention of the first order. The high cost of labour, especially in the

A PRIMITIVE FORM OF CRUSHER USED IN INDIA.

Western centres of mining activity, and the magnificent, or extravagant scale on which mining and metallurgical operations are conducted, involving the handling and treatment of enormous quantites of raw materials and finished product, have necessitated the replacement there of hand labour by machinery more universally than in Europe.

This tendency manifests itself in every branch of the metallurgy of all the metals, but is, perhaps, most conspicuous in the department of rock and ore crushing. In Europe, and even in England, women may still be seen spalling ore with spalling hammers, not because the ore is rich, and because waste is reduced by the production of less fines under the blow of the hammer than between the jaws of a crusher, but because many of the smelting works are still unprovided with rock breakers.



SECTION OF A BLAKE CRUSHER, BUILT BY E. W. BLAKE, NEW HAVEN, CONN, U. S. A.

These machines, of several designs, but all of American origin, have gained admission into every large metallurgical establishment the world over.

I. They represent the machinery employed, as a general rule, to reduce lumps, of rock and ore, as they come from the quarry or the mine, to sizes suitable for road metal or railroad ballast, or for smelting and treatment in the concentrating mill.

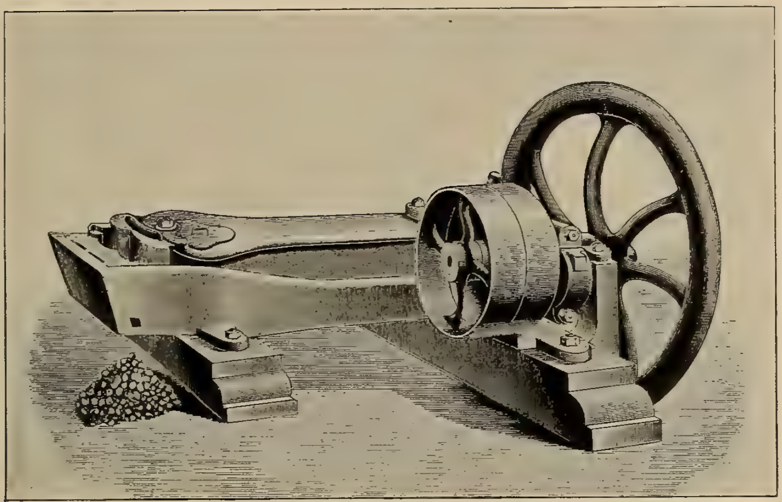
II. The rock breaker is, therefore, the preparatory implement of rolls and such other appliances as are used for the granulation of ores,—that is for reducing them to gravel size, as well as of

III. Stamps and the multitude of devices which have been proposed for the pulverisation of ores and other materials.

Into these three classes all machines for crushing and grinding naturally divide themselves, and under these three heads it will be convenient to refer to those which have met with general acceptance and some few which are noteworthy, not because particularly valuable, but because they represent distinct types or the application of novel principles.

I. Although in some few mines and quarries, where masses too large for admission between the jaws of a breaker, have to be handled, a trip hammer is employed to reduce the lumps to more convenient size, initial crushing is, as a rule, effected by one or other of the rock breakers.

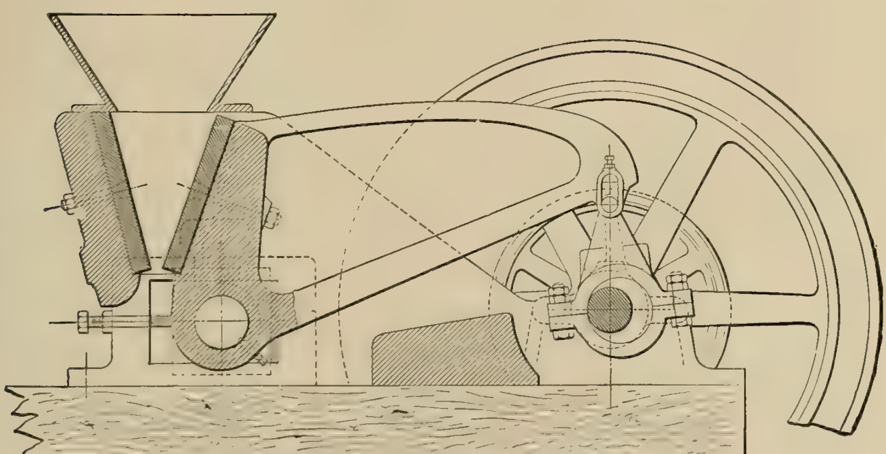
The first stone crusher, suggested, it is said, by the nut-cracker, was patented by Eli Whitney Blake in 1858, and contained all the essential elements of the most recent Blake crusher,—the fixed and movable jaws, the pitman and toggles. But the parts were inverted. Motion was communicated to the top of the movable jaw which rested on a step, instead of being suspended as in the recently constructed Blake crusher, and opening and closing at the point of discharge. There are, however, certain breakers, notably the Dodge, which retain the original jaw movement, on the plea that a more uniform product is obtained, and that finer crushing, when that is desirable, can be secured. But the concurrence of preference, if gauged by use, is in



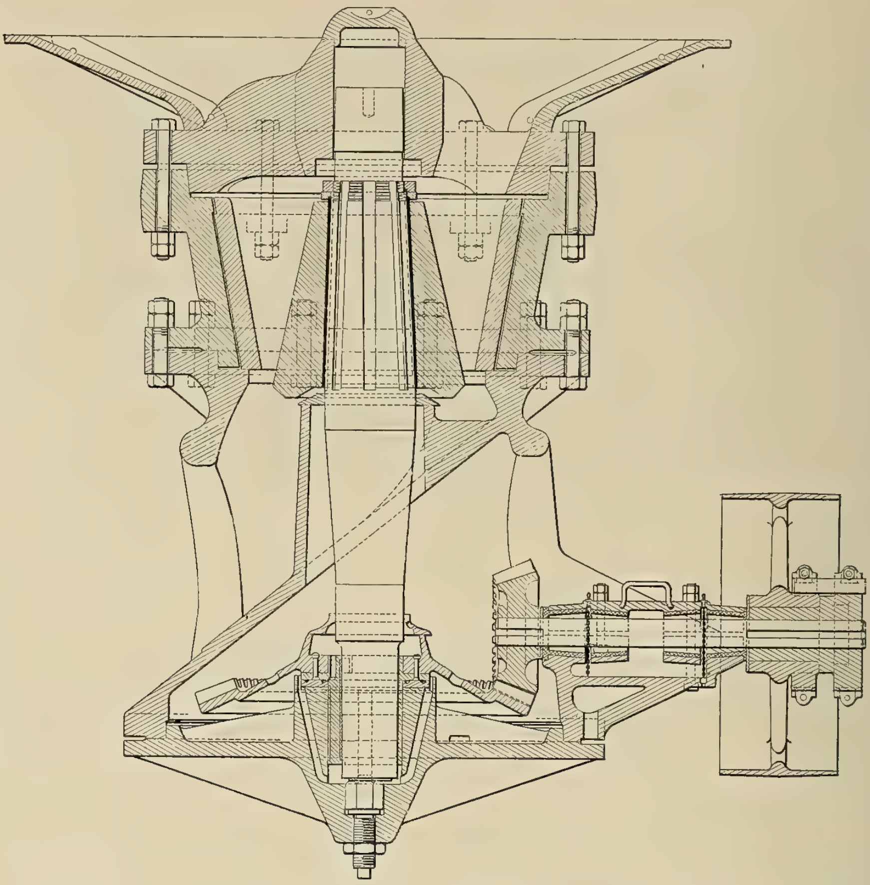
THE FORSTER CRUSHER, BUILT BY MESSRS. FRASER & CHALMERS. LONDON AND CHICAGO.

favour of the modern Blake design, when that type of breaker is chosen.

There is, however, a growing demand for breakers of the Gates-Comet type. The original of these machines seems to have been patented in 1865, by Gates & Fraser, then in partnership. In it a roller shaped, horizontal jaw was made to oscillate in a trough, open for feed at the top, and discharging through a slot in the bottom. The next step was to suspend or support on a step an inverted cone in a cup-shaped mortar, open at the top and bottom, and impart to this conical jaw an oscillating and slightly gyrating motion. This form of movable jaw, being circular, crushes all round its periphery, and thus the strain is not so localised as in the flat-jaw breakers. There is much less risk of breakage. Where large capacity is demanded and vertical space can be spared, especially if the rock to be crushed is tough, this type has decided advantage over the Blake. It is only in mere structural details that the Comet, the Gates, the Lowry, the McCully, and others of



A SECTIONAL VIEW OF A DODGE CRUSHER.



SECTIONAL VIEW OF A GATES CRUSHER, BUILT BY THE GATES IRON WORKS, CHICAGO, ILL.

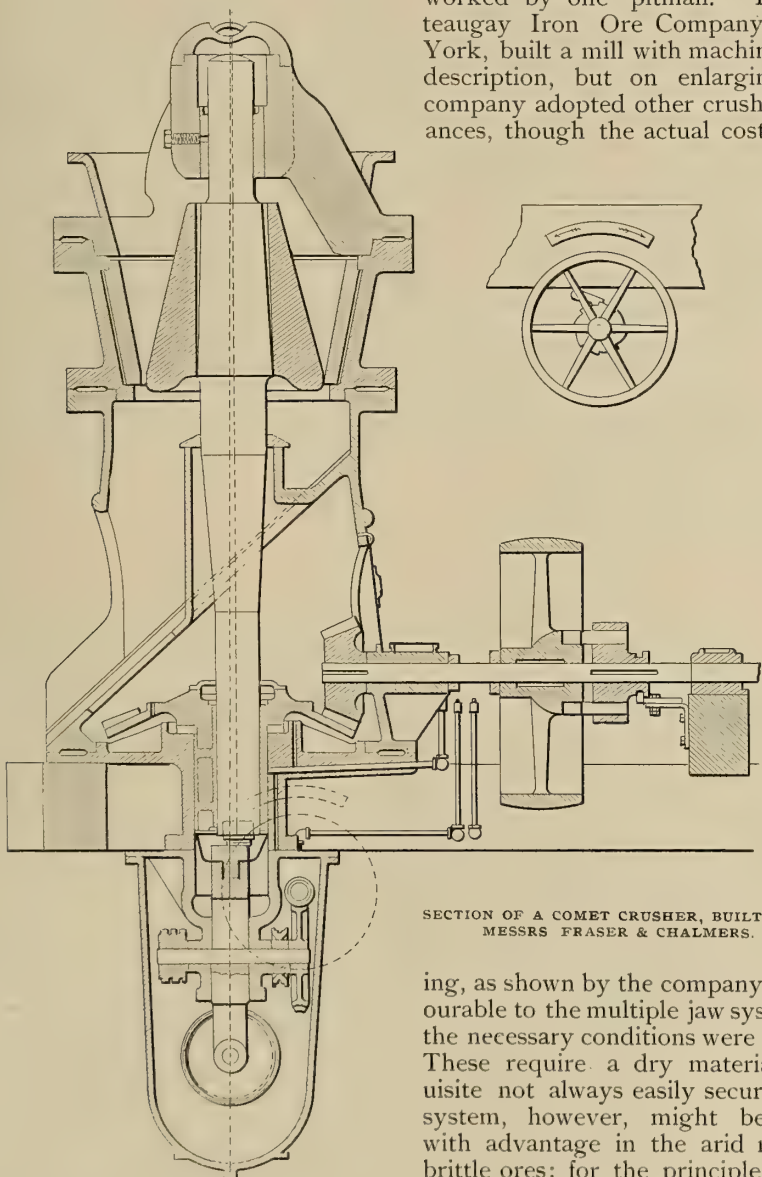
this general form of breaker differ.

The capacity of any of these breakers depends, of course, on the rock crushed, the regulation of feed, and the setting of the jaws. A large-size standard Blake crusher of 20″x15″ receiving area, with jaws set 2 inches apart at discharge, will crush from 12 to 15 cubic yards of quartz per hour, with the consumption of 14 H.-P. The smaller sized Gates-Comet crusher will not crush more per horse-power than the Blake, but from the design of these machines, it is possible, without making them cumbersome, to build circular crushers of much greater capacity than the Blake. The largest machine made by the Gates Company stands 12 feet high, has a receiving hopper 12 feet in diameter, and crushes 100 cubic yards of road ballast per hour, but absorbs 125 H.-P.

In the Schranz breaker, a German machine, which combines some of the features of the crusher and the rolls, the movable jaw presents a convex surface to the fixed jaw, and receives a rotary instead of a reciprocating motion. It thus serves as a granulator as well as a crusher, for the discharge end of the rotary jaw can be adjusted at a fixed distance from the stationary. In the Foster breaker the movable jaw has an oscillating motion which constitutes it a grinding, as well as a crushing, mill. The Booth combination breaker, manufactured by Gates, is provided with an overhanging jaw, as in the Blake, beneath which, in the same frame, is a Dodge jaw. The

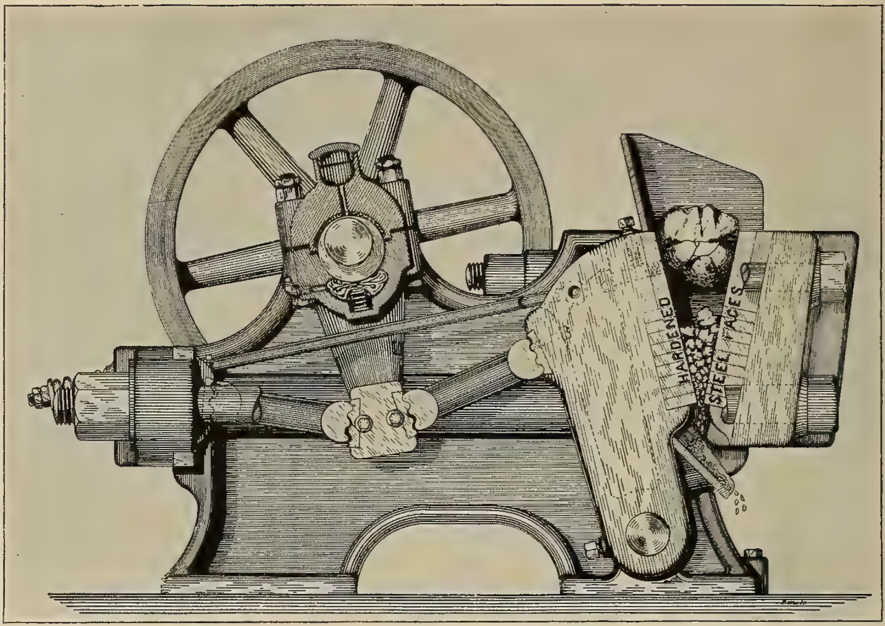
manufacturer claims a product of coarse stuff equal to that of a Blake, and owing to the previous disintegration, a double capacity of fines for the Dodge jaw. There are, however, manifest disadvantages in requiring a single machine to perform a double function.

Theodore A. Blake has attempted to extend the use of the Blake crusher to the granulation of ore and rock by placing a series of breakers one above the other, with jaws set closer and closer, the breakers for fine crushing being provided with multiple jaws, worked by one pitman. The Chateaugay Iron Ore Company, of New York, built a mill with machines of this description, but on enlarging it the company adopted other crushing appliances, though the actual cost of working, as shown by the company, was favourable to the multiple jaw system when the necessary conditions were observed. These require a dry material, a requisite not always easily secured. The system, however, might be applied with advantage in the arid regions to brittle ores; for the principle involved is sound and the machinery simple.

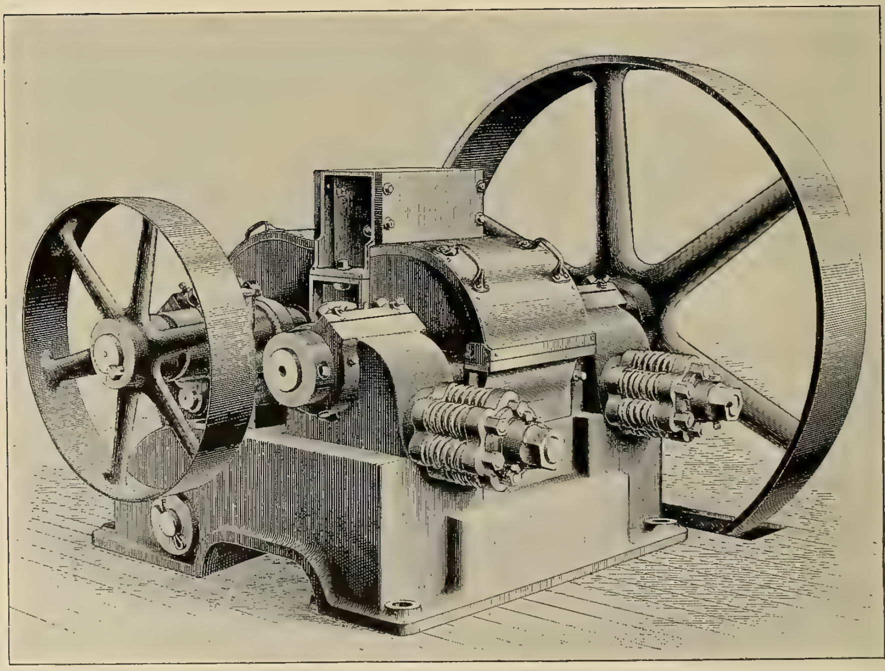


SECTION OF A COMET CRUSHER, BUILT BY MESSRS FRASER & CHALMERS.

II. As a rule, the granulation of ore is effected by rolls, and the reduction to a size intermediate between coarse and fine is generally effected by them



STANDARD ORE BREAKER, BUILT BY S. R. KROM, JERSEY CITY, N. J , U. S. A.

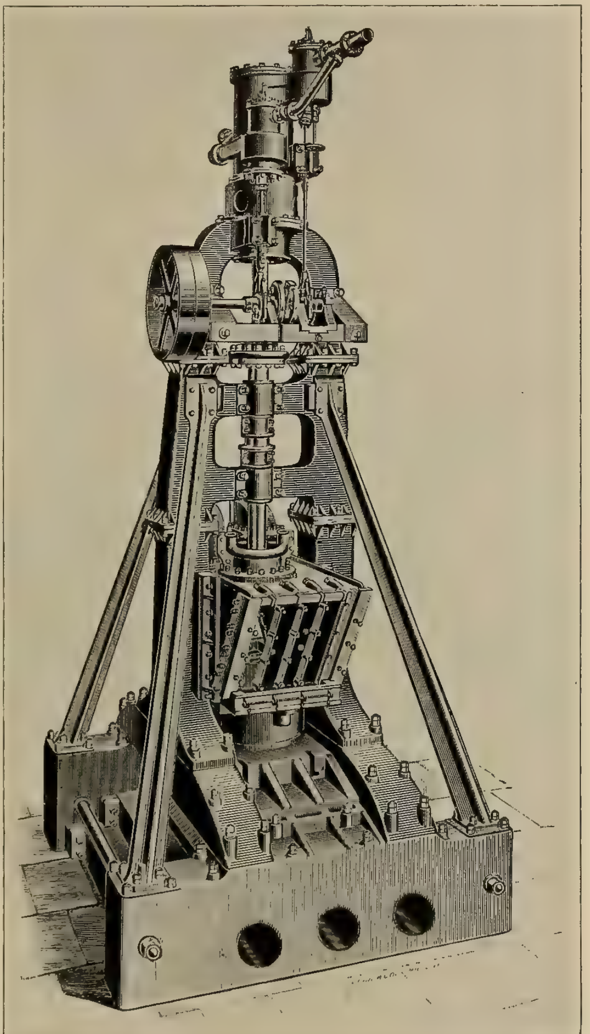


A SET OF KROM CRUSHING ROLLS.

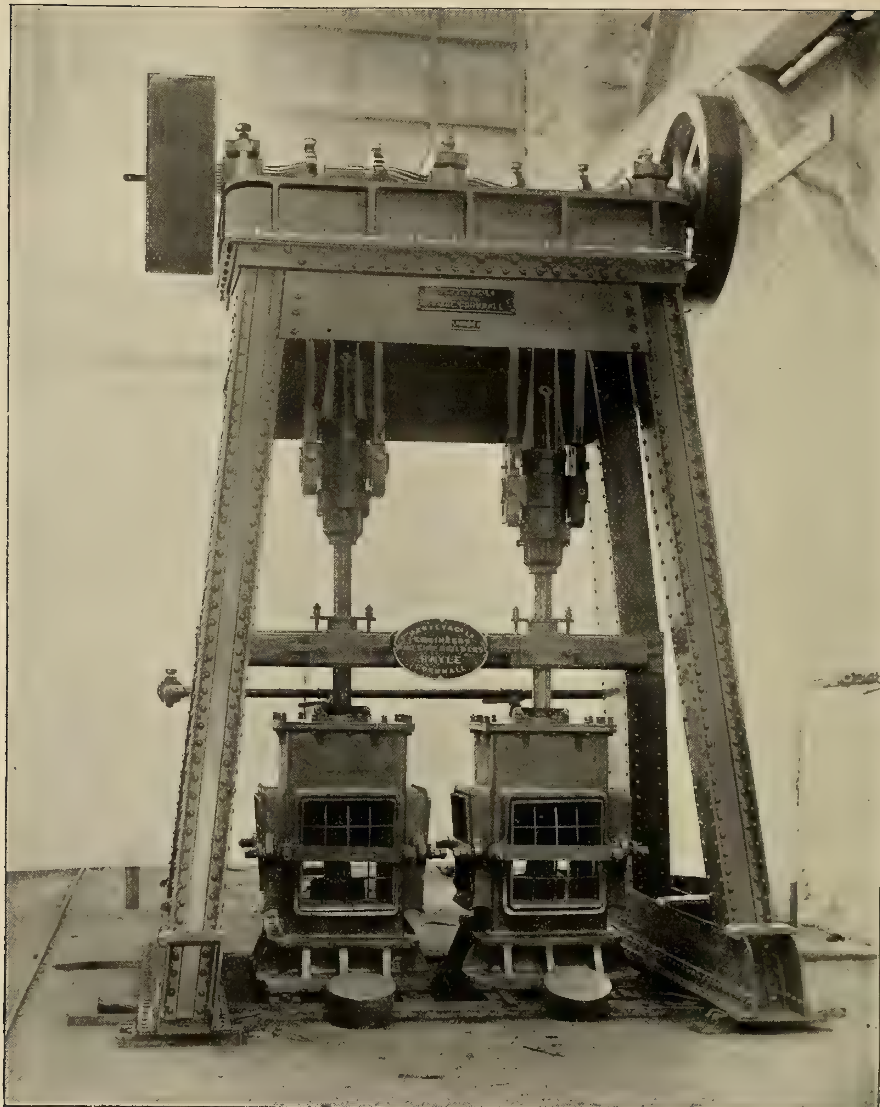
as a preparation to concentration. But on Lake Superior, the steam stamp was first adopted and is now exclusively employed for that purpose, and its use has extended to other regions.

Two rolls, revolving on horizontal shafts, and kept in apposition by weighted levers, were first applied by Taylor at the Wheel Crowndale mine, near Tavistoch, in 1804, and have ever since retained the name of "Cornish rolls." Many structural changes in the running gear, in the method of holding the rolls in contact and in the frame have been introduced by different manufacturers, but no special design has met with universal adoption. In the oldest form the rolls were driven directly from the engine by geared wheels; now a belt is invariably interposed, but motion is still usually imparted directly to one roll only and from it to the other by gearing, the speed being reduced by toothed wheels and pinions. Unless the gearing be carefully housed, especially where crushing dry, the wear and tear on the teeth is excessive, and therefore those styles of machines where each roll is driven by an independent belt are superseding the older designs, not only on account of reduced wear and tear, but because they permit of a higher speed, which is the direction in which modern practice is tending.

The substitution of steel tires for cast-iron, moreover, renders a high speed possible. It is claimed by Mr. S. R. Krom, that rolls, when made with such perfect means of adjustment, and of such excellent material as those which he manufactures, and which run at a speed of 125 revolutions per minute, can be, and are, at the Bertrand mill, in Nevada, in the United States, and elsewhere, employed for fine crushing; that they are cheaper than stamps in original outlay, and that they crush through the same mesh at a less cost per ton of pulp than stamps, both in the items of wear and tear and of fuel consumption.



A STEAM STAMP, BUILT BY THE E P. ALLIS CO., LONDON AND MILWAUKEE, WIS., U. S. A.



A STAMP MILL, MADE BY MESSRS. HARVEY & CO., LTD., HAYLE, CORNWALL.

These calculations are certainly not confirmed by the experience of most mill men who have applied rolls to the pulverisation of rock; but the contention is well made by the advocates of rolls that comparison can be fairly made only between the work of the very best of both classes, and certainly the number of rolls in the market, of defective design and of wretched workmanship, is greatly in excess of stamps of equally faulty construction. Making the shells of the very best cast-steel ensures their uniform wear. A slight difference in the speed of the two rolls, or giving them a slight taper, seems to produce the same effect.

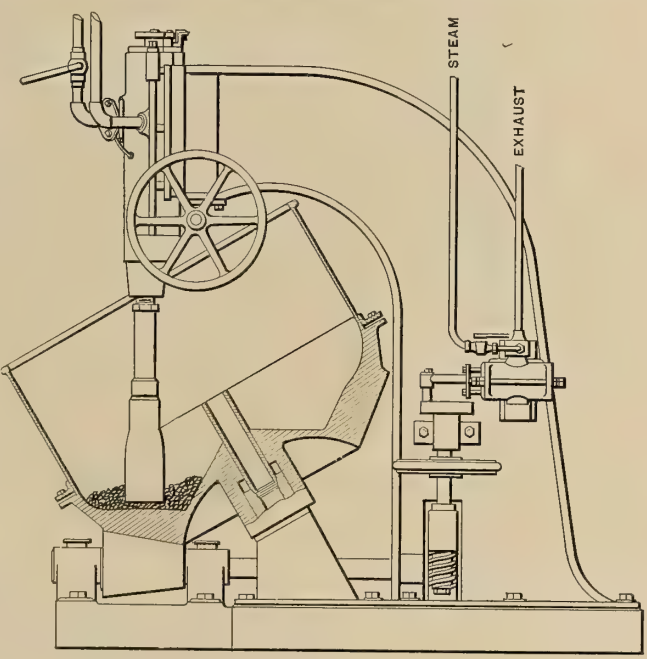
The employment of rolls in ore concentrating works was universal till the adoption of stamps by the Lake Supe-

rior mills. This departure was forced upon the lake companies by the liability of mass copper to clog the rolls. Once stamps, heretofore used only for fine crushing, were introduced for coarse crushing, changes in their construction imperatively followed to fit them for their new uses, and a completely new type has been evolved in the steam stamp. When rolls were abandoned, the gravity stamp first took their place, then a pneumatic stamp had a short trial, but all other forms, in time, yielded to the steam stamp, first designed by W. Ball, of Chicopee, Mass., U. S. A.

Ball is said to have erected his first mill at the Copper Falls mine on Lake Superior, and there to have driven his stamp by steam, employing the rudiments of the gearing still in use, but discharging by only one gate from the mortar. At the Pewabic mill Ball added another gate. As now constructed, the mortar discharges through four gates, and the machine has been so improved in every detail, that one stamp head, moved by a 20-inch cylinder with a 30-inch stroke, crushes, of hard rock, 250 tons a day, coarse for concentration, or 150 tons fine for amalgamation. Each stamp is an isolated machine. The head is attached directly to the rod of a piston moving in a vertical steam cylinder, which is supported on four heavy converging pillars. These rest on a solid frame, and hold in place the mortar.

This, till recently, was built on an elastic bed, but it is now made to rest on a solid bed plate, whereby the yield has been notably increased. The steam valves are operated by eccentrics and rods, which derive their motion from some external source of power, generally the main shaft of the mill, through one or more countershafts. The weight of the superstructure of a single stamp is about 140,000 pounds. While it will do a stupendous amount of work, it consumes 8 or 9 tons of coal daily; absorbs 150 H.-P. and requires, in order to evolve its full efficiency, that it be supplied with not less than 7000 gallons of water per ton of ore crushed. The original Ball stamp has been modified by the inventor himself, by Leavitt, the eminent engineer of the Calumet & Hecla Company, and by others.

The E. P. Allis Company claims that one of their stamps with the Reynolds-Corliss gear and the solid cast-iron anvil blocks, crushed, through a 3-16 mesh screen, 1920 tons of hard cutting conglomerate rock in six days, or 320 tons daily. Outside of the Lake Superior region in the United States the steam stamp has replaced rolls in the Anaconda concentrating works, and in the magnetic separating works of the Tilly Foster mine in New York State. Its chief recommendation is the enor-



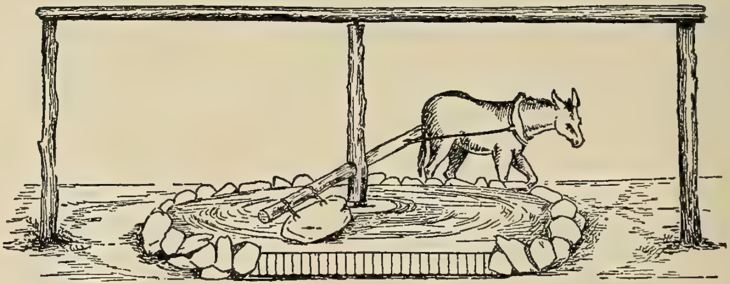
FISHER'S ROTATING BED STAMP.

mous amount of work it can do in so small a space, and the advantage it affords of delivering the stamped gravel by a flood of water, in a restricted channel, to the sizing apparatus and gigs.

There is probably no saving in the actual cost of crushing a ton of rock, in favour of the stamp, and it makes more slimes,—an objectionable feature in a concentrating mill,—than rolls; but when as much as 4000 tons of ore have to be crushed a day, as is done by the Calumet & Hecla and the Anaconda companies, concentrating machinery is a prime necessity. Nevertheless, in the magnificent concentrating mill of the Boston and Montana Company, at the Great Falls of the Missouri, rolls, after comparative tests, have been preferred to stamps.

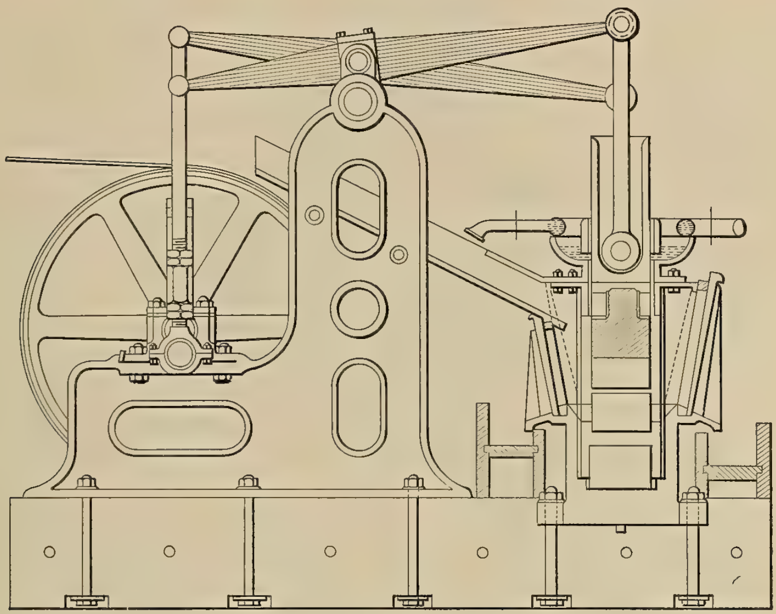
FROM AGRICOLA, 1546.

A STAMP MILL OF THE MIDDLE AGES.



THE ARASTRA. ONE OF THE EARLIEST CRUSHING MACHINES USED IN AMERICA.

III. No other machinery than the above is extensively used for the granulation of ores; but when we need a



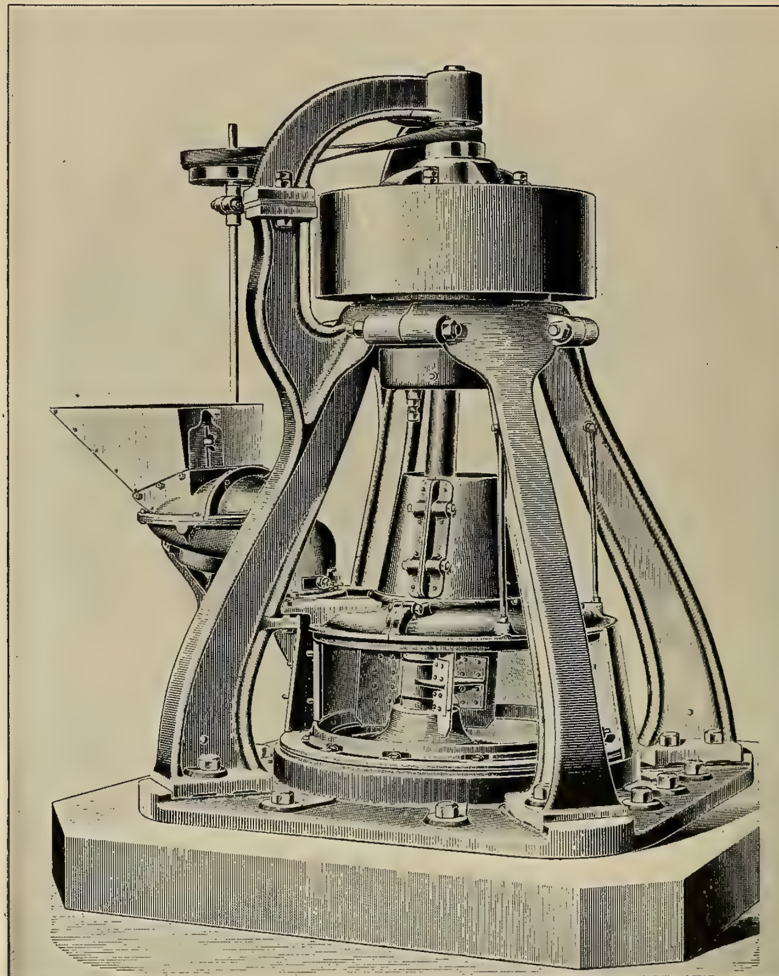
DUNHAM'S RECOIL STAMP.

pulveriser, a host of competitors present themselves. For the fine crushing of ores the stamp battery has maintained its prominence from times immemorial. Agricola, in his *De Re Metallica*, published in 1546, describes and illustrates dry and wet stamp batteries, the former for coarse, and the latter for fine crushing, which do not differ in any essential detail from the batteries with rectangular wooden stems, clumsy wooden shafts, and wooden mortars which may be seen in operation in some places in Europe to-day.

This old-fashioned style disappeared from the United States long ago, but the up and down stamp, with stems of iron, and dropping in an iron mortar, continued to be preferred, on the American Lakes to the revolving stem and stamp, till displaced by the steam stamps. Although the first revolving steam battery is said to have been erected at the Quincy mill by Gates & Fraser about 1860, California became at once its home and gave her name to it.

There are two distinct styles in use for gold milling, and of these there are numerous variations. The choice is usually determined by the character of the ore to be treated. If its gold yields freely to amalgamation, the California type with narrow battery box, low discharge and rapid, slight fall of a very heavy stamp, crushes a very large quantity to sufficient fineness and leaves the pulp long enough in contact with the mercury to ensure the arrest of the gold. Where the gold ore is more refractory, what is known as the Colorado battery is selected, the features of which are the reverse of the above, namely, a roomy battery box with high discharge and a light stamp and stem with a long drop,—conditions which favour the production of a large quantity of slime, though at the expense of a much lower yield in quantity crushed than the California battery. These conditions ensure contact of the pulp with the mercury for a proportionately longer time.

When stamps are used for dry crushing, as, for instance, where the product has to be roasted, preparatory to the extraction of the gold and silver from certain classes of ore, the battery is constructed with discharge ports be-



THE GRIFFIN MILL, BUILT BY THE BRADLEY PULVERIZER CO., LONDON AND BOSTON, U. S. A.

hind and before; but the stamp mill is not a desirable instrument for the crushing or pulverisation of a dry material. Instead of depending on the blow of the stem and stamp, raised by a cam, or instead of using the direct impact of a stamp head propelled by a steam piston, reciprocating motion is given by a crank in the Husband stamp. It is a pneumatic stamp and is used extensively in the tin regions of Cornwall. The crank communicates motion to the stamp head through an air cylinder which regulates the blow. The Husband stamp was used by the Temescal Tin Company in California, but its capacity per horse-power is less than that of a well designed California stamp, being on an average 25 tons per day per stamp head through a 36 mesh screen, with the consumption of 22 H.-P.

There are many other forms of stamps. In the Dunham recoil stamp the stem is raised and depressed by a walking beam; the Fisher stamp has a rotary bed; in the Patterson elephant stamp the blow is given through a bent lever from a crank shaft, the shock being broken by a spring. But if we

may accept the choice of the miner as a verdict on the advantages of these and others, as compared with the California stamp, we must pronounce in favour of the last. Simplicity of design and infallibility of operation is above all what he demands.

The substitutes for the stamps are very many. All inventors preface the advertisements of their pulverising wares, by pointing out the anomalies of the stamp battery construction and operation, the waste of power it involves, the space it occupies to the work done, and the disproportionate production of slimes. But despite all its admitted defects no opponent has supplanted it. The various pulverisers, apart from the stamp batteries, may be classed as follows:—

1.—Those which utilise the grinding action of rollers revolving against circular disks, and are, therefore, modifications of Cornish rolls.

2.—Those whose grinding agents are rolling and falling bodies confined in a barrel, revolving horizontally, and which, therefore, call into play substantially the same action as the previous ones.

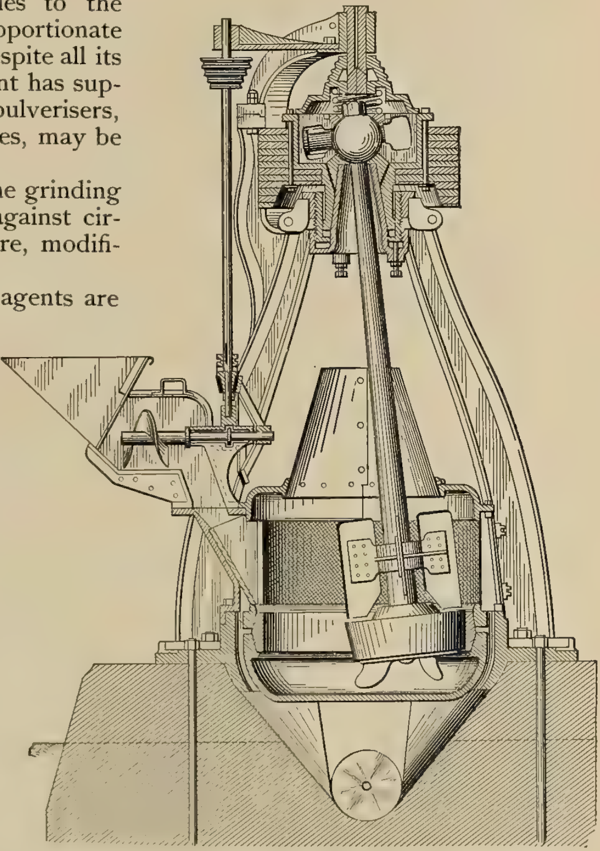
3.—Those which imitate the old-fashioned burr stone mill, and grind between two corrugated surfaces, generally of metal, and placed vertically.

4.—Those which depend on the stroke of a bar or paddle in rapid motion against a suspended particle, and, therefore, reproduce the action of a hammer.

5.—Those which apply the grinding action of particles against particles when agitated by violent air currents, and therefore create miniature whirlwinds and their disintegrating effects.

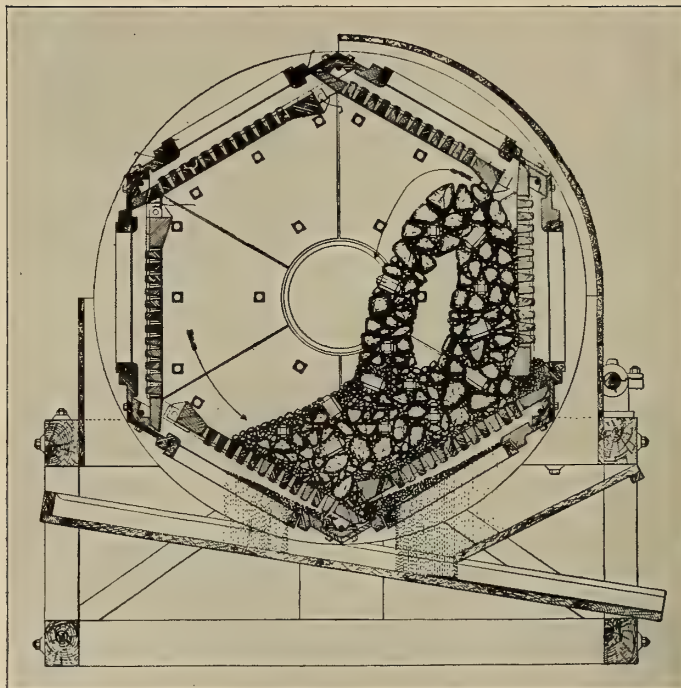
1.—The most primitive form of grinding machinery is the *trapiche*, still used in Bolivia and remote mining regions of South America,—a hollow stone mortar in which a stone pestle is made to revolve and oscillate by two men who bestride a see-sawing bamboo cane secured to the pestle.

The next simplest form is the *arrastra*. It consists of a circular basin of stone within which a block of stone is dragged by a mule. In this extemporised contrivance not a little gold quartz ore is crushed and amalgamated by the Western American miner, when testing his gold vein on a working scale, or when compelled, by lack of means, to forego the use of more expeditious and economical machinery.

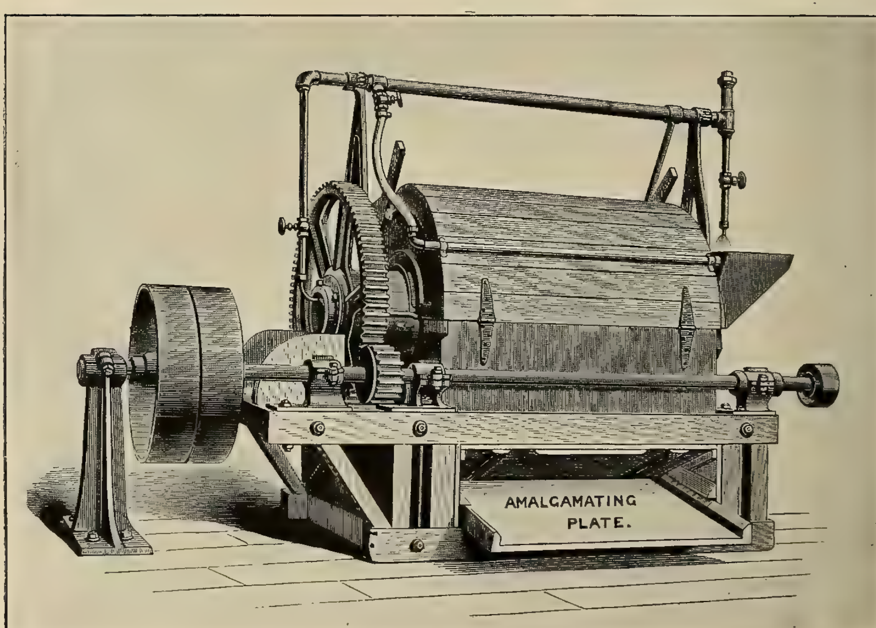


SECTIONAL VIEW OF A GRIFFIN MILL.

The development in iron of this relic of the stone age is the Chile mill. In it two iron rollers, revolving on a horizontal axle, attached to a vertical driving shaft, crush the material under treatment in an iron pan. Every large



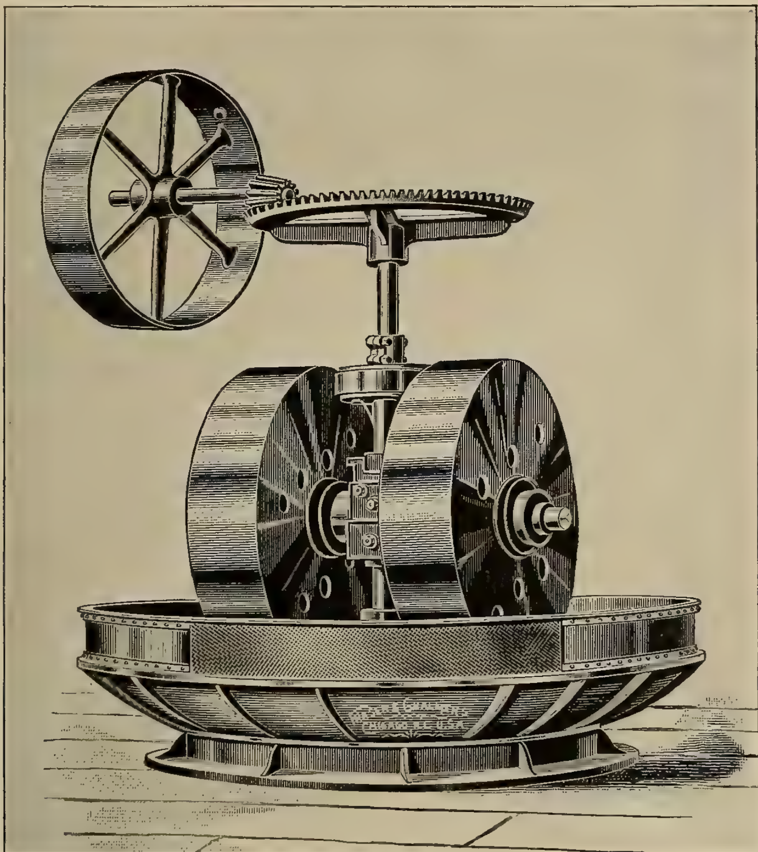
SECTION OF A DODGE MILL.



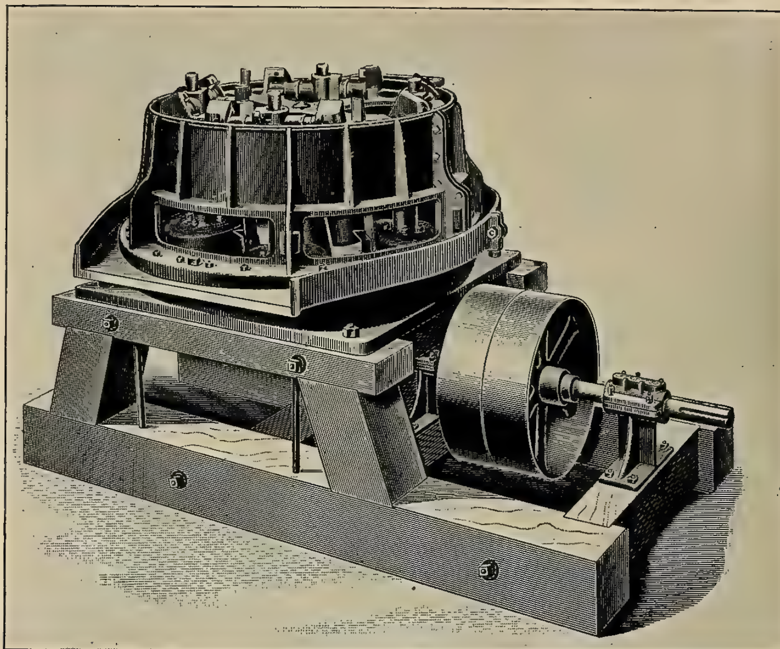
THE DODGE MILL, BUILT BY THE DODGE MINING MACHINERY CO., SAN FRANCISCO, CAL.

manufacturer has modified the shape or arrangements of the component parts of the Chili mill and given distinctive names to his designs. For simultaneous grinding and mixing, as where an intimate blending of moist quartz and clay is required, the Chili mill takes precedence of all other forms of crushing machinery. It is also applied to the pulverisation of ores especially when extreme fineness is desirable. A well constructed mill will crush from 15 to 20 tons per day through a 100 mesh screen, or 60 to 70 tons of jig tailings.

But the aim of most inventors in this direction has been to perfect a pulveriser in which the rollers work on a vertical spindle and press by centrifugal force, when the driving shaft revolves rapidly, against a rigid circular ring—rather than to improve the construction of the slow-moving Chili type of mill. The Huntingdon is the most widely used of the centrifugal roller mills. Four rollers, keyed to as many vertical spindles, revolve horizontally against a ring die, the pulp being discharged, as rapidly as it attains the desired fineness, through screens secured in five ports, which open on the walls of the cylinder. When used for gold ores amalgamation is effected in the mill, and on an apron as in the stamp mill. It is essential to success that the ore be reduced to coarse particles, say by rolls, before entering the mill. In the Bel-



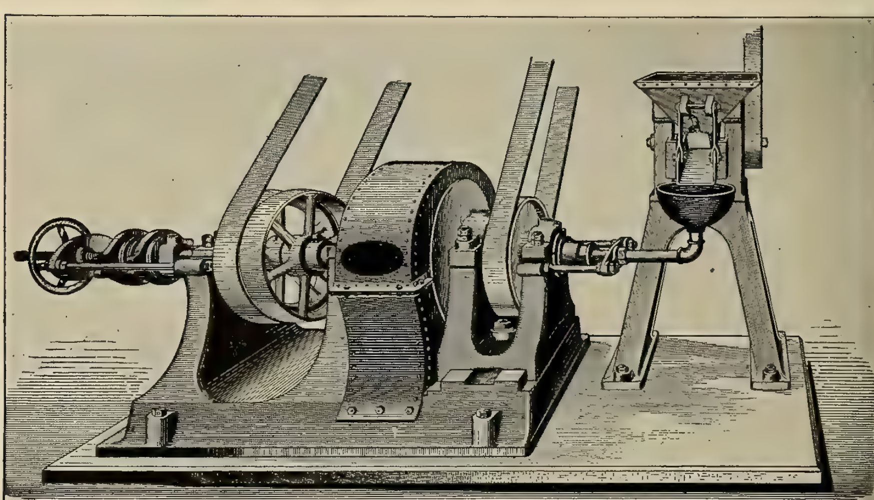
A CHILI MILL.



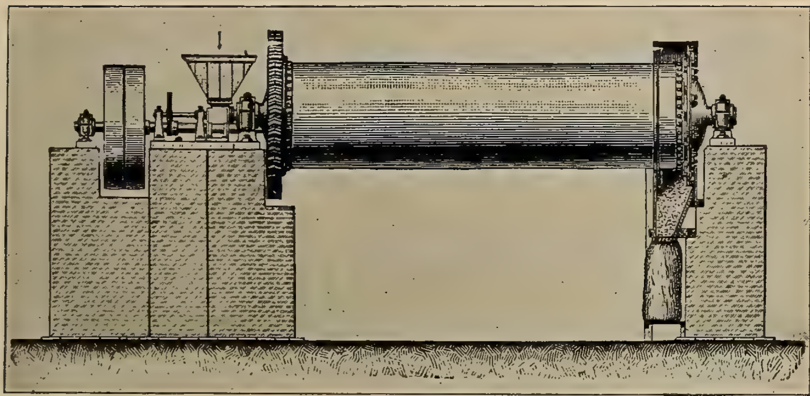
A HUNTINGDON MILL, BUILT BY MESSRS. FRASER & CHALMERS.

mont mill, at Telluride, Col., U. S. A., four 6-foot Huntingdon mills, fed from four separate sets of coarse rolls, crush 80 tons of rock daily. The Huntingdon mill has been found well suited for regrinding the coarse tailings and the middlings of a concentrating mill.

The Griffin mill employs a single roller, which is attached to a vertical shaft suspended from the running gear by a universal joint. It is, therefore, free to swing with great force when rapidly revolved against the circular ring die. A number of mills have, at one



THE HEBERLE MILL, BUILT BY MESSRS. FRASER & CHALMERS.



A CRUSHING MILL, MADE BY MESSRS. F. L. SMIDTH & CO., LONDON.

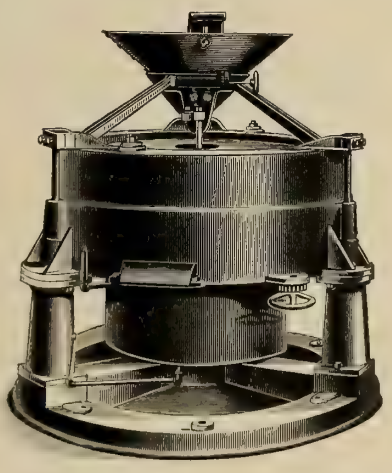
time and another, been constructed, such as the Thompson pulveriser, to take advantage of the tremendous centrifugal force of free balls, made to revolve with great speed, and, in revolving, to fly off and crush whatever is interposed between them and the confining walls of the cylinder; but none have come into extended use.

2.—For certain purposes balls rolling round within a barrel, rotating horizontally, make a most efficient pulveriser. The Lowe pulveriser contains two large cast-iron balls, 14 inches in diameter and weighing 1200 pounds, which revolve in compartments, 9 inches apart, into which central section the ore is fed, while the pulverised ore falls into two outer sections provided with revolving elevators. The mill is said to crush 15 tons of soft ore daily at the Angles gold mill in Calaveras county, in California.

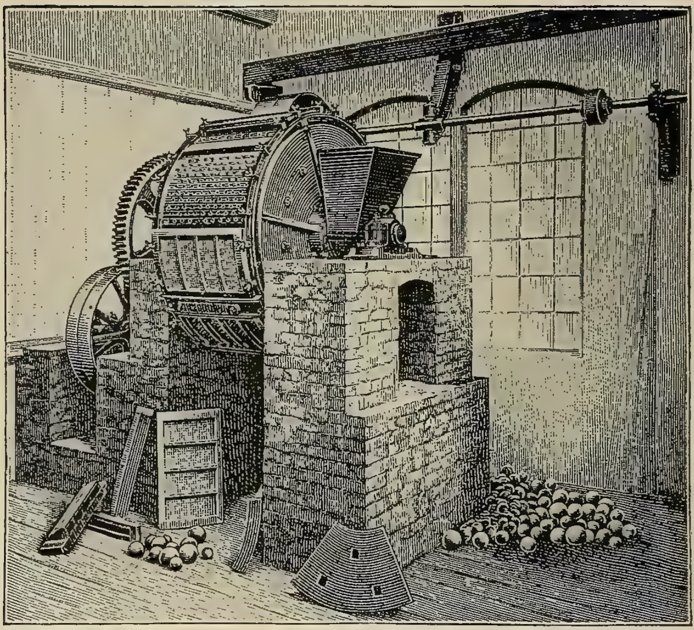
The Tustin mill is a drum, 54 inches in diameter and 18 inches long in which roll two cast-iron cylinders of 700 to 1000 pounds respectively, the periphery of the drum being slotted to permit of the discharge of the crushed ore. The Dodge barrel pulveriser has had extended patronage, and a well designed and well-constructed ball-mill is manufactured by F. Krupp, of Magdeburg, Germany. It and the Dodge mill have continuous feed and discharge, the balls and material under treatment revolving on false lining plates, attached en echélon to the perforated shell of the mill. Krupp claims that his large mill, of 7 foot diameter, will crush, through a 40-mesh screen, over one-half ton of ore per hour with an expenditure of from 12 to 15 H.-P., while it will grind twice as much if passed through a twenty-mesh screen.

The Janisch ball mill of the same general design as the Dodge and Krupp, and the Schmidt mill,—a long cylinder continuously fed and in which the balls are kept in place by a diaphragm,—are foreign mills used in the United States for grinding cement.

When employing a simple ball mill with intermittent discharge on moder-

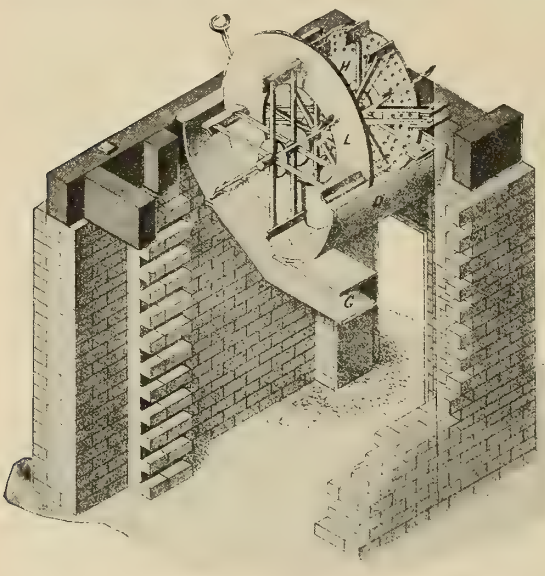


THE STURTEVANT MILL, MADE BY THE STURTEVANT MILL CO., BOSTON, MASS.



BALL MILL, MADE BY THE FRIED. KRUPP GRUSONWERK, MAGDEBURG-BUCKAU, GERMANY.

ately soft material, like matte, the author has found hard stones, like old Belgian paving blocks, to be much more efficient than balls. They crush the ore through a pounding rather than a grinding action and give good results.



THE INTERIOR OF A WHELPLEY & STORER PULVERISER.

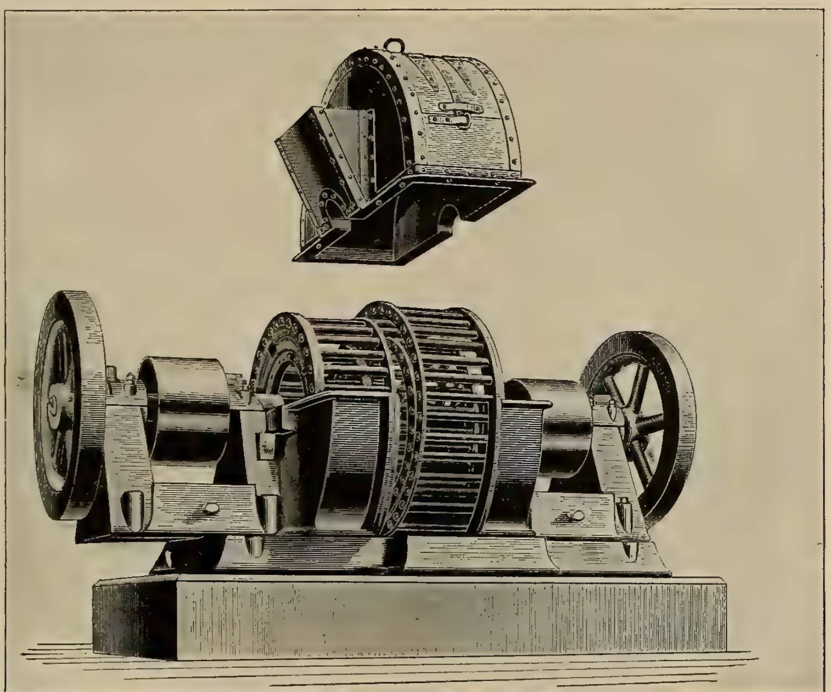
3.—Grinding between mill stones can probably claim higher antiquity than any other method. The primitive housewife who was also the primitive miller, used it on corn, and the primitive mine, and metallurgist, especially of South America, still apply it to ores. But for both purposes, stones have been generally displaced by iron and rollers have superseded the revolving disk. The revolving cylinder of the Hungarian system has driven the burr-stone out of the large flouring mills, and some form of roller mill is preferred to even revolving disk mills by metallurgists ; nevertheless improvements in design and in structural material of mills with two or more revolving disks, or with a cone revolving in a rigid cup either vertical or horizontal, like our coffee mills, still fill an important place among the multitude of grinding contrivances which are now in use.

For drugs, spices, and soft substances, where great fineness must be obtained and the wear is slight, these classes of mills retain the preference, but for the pulverisation of hard material, like most ores of the metals, they are generally rejected. The vertical disk mills of the Heberle and Bogardus type which of late years have been used, perhaps more than any other, in American ore concentrating works to regrind tailings, occupy a small space, but their capacity per machine is small, the wear and tear considerable, and the loss of time in renewals great. Formerly, a long line of Heberle mills was used in the Anaconda concentrator to grind tailings, but they have been replaced by a single steam stamp.

The Schranz mill is highly commended. In it a slightly coned ring revolves slowly and communicates motion by contact with three rollers, set radially to the revolving cone, and whose proximity thereto can be regulated by set screws. They can be so adjusted as to do the crushing progressively and with but slight grinding action.

4.—A class of mills which claim to do their work by beating the particles to be ground against one another, or creating currents of air which produce the same effect, contains many members; but all are open to the objection that the moving parts are propelled with great velocity, and even if they are not themselves worn away with undue rapidity, portions of the revolving machinery wear unequally, and, the balance being disturbed, the mill tears itself to pieces. As long as these cyclonic pulverisers remain in perfect adjustment they do work rapidly and in some cases economically, but no test of their efficiency is conclusive which does not extend over a sufficient period of time to develop possible frailties.

It has been proposed more than once to dispense altogether with mov-

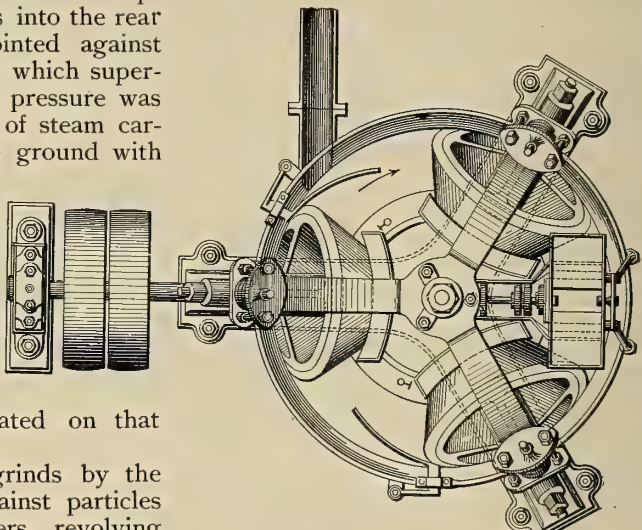


A DISINTEGRATOR, BUILT BY STEDMAN'S FOUNDRY AND MACHINE WORKS, AURORA, IND., U. S. A.

ing parts, and to use the impact of particles propelled by steam or air under pressure to effect their own pulverisation. In 1882 a company had a mill in steady operation in New York City which was operated on this principle. The material to be ground was stored in hoppers whose discharge was into the rear of two conical jets, pointed against each other, and through which superheated steam at a high pressure was blown, the opposing jets of steam carrying the particles to be ground with such violence against one another as to reduce them to powder. The rapid destruction of the nozzles was one of several reasons which militated against the economical success of that particular mill and of any other operated on that system.

The Sturtevant mill grinds by the attrition of particles against particles in two hollow cylinders revolving rapidly in opposite directions within a housing, lined with a screen of the desired fineness. It is used more successfully for granulating ore than for very fine grinding, as once the particles have been reduced to a certain fineness, the force of their impact is insufficient to rapidly effect their own subdivision.

Another class of mills is claimed by their inventors to combine the action of the blow with the self-grinding action of the material under treatment. Thirty years ago great hopes were entertained of the displacement of all others by the Whelpley & Storer pulverisers. The machine consisted of a cylinder, divided into two compartments by a diaphragm with an adjustable central opening. On one side of the diaphragm revolved beaters, attached to a spider, speeded to over 1200 revolutions, while on the other side the vanes of a fan drew the powder through the gate of the diaphragm and blew it into dust chambers whose walls and roof were of canton flannel. As long as the shaft and its attachments were in perfect adjustment and balance, the capacity of the machine was extraordinary. It was used on a large scale, and continuously, for grinding bones, but when applied to hard ore, though at first starting it would reduce to almost impalpable powder a ton an hour of roll-crushed



PLAN OF A SCHRANZ MILL.

quartz, the yield soon feel off and the mill commenced to destroy itself,—a fate which is liable to overtake all machinery designed to do rough work, through very rapid motion.

At about the same period another type of pulveriser made its appearance in the market, known as the Carr disintegrator. The principal component parts of this were two large disks, from each of which protruded a circle of steel bars.

The diameters of the circles, were different, and as the disks and bars were made to revolve in opposite directions, through the medium of a hollow shaft, the material to be ground was violently thrown from bar to bar, and broken into powder by dint of both a hammering and attritive action. This design of the machine has undergone many modifications at the hands of different manufacturers, and it still commands an extended use on both sides of the Atlantic.

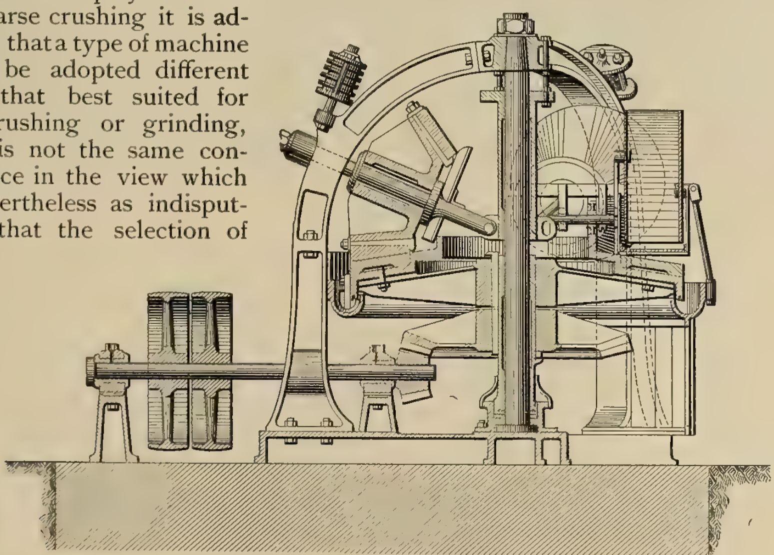
As disintegrators are now built, the

disks with protruding spokes are replaced by cages, fitting within each other, but hung on different shafts, and run by independent pulleys on opposite sides of the housing. The following interesting table is taken by Kunhardt from the *Jahrbuch der Bergakademie zu Loeben* :—

The comparative table given below proves, for example, that no machine, or type of machine, possesses every qualification of excellence. Had the comparative test been extended to different substances, it would have been still more apparent, that while one of the ma-

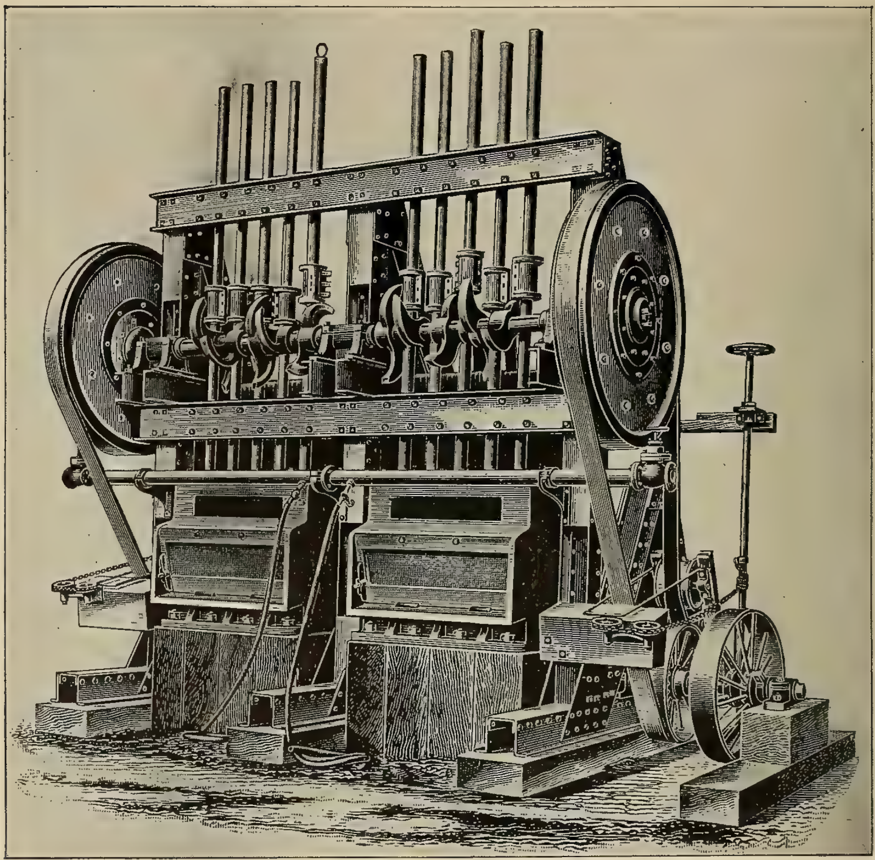
	Order of Efficiency, 1st, 2d, 3d or 4th for the			
Comparison for	Heberle Mill.	Dingey Mill.	B. & H. Disintegrator.	Fine Rolls.
Minimum production of fine pulp	1	4	2	3
Labour, power and lubrication	4	3	2	1
Wear per ton of ore	1	3	4	2

The Heberle mill may be taken as an example of a disk mill, and the Dingey as an example of a roller mill; the disintegrator was of the Brest & Huebner pattern. In the foregoing sketch the aim has been to point out the various forces which mechanics have called to their aid in designing machinery for the disintegration of solid substances, and the very great diversity of design in the machinery, which has in consequence resulted from the diversity of the action brought into play. While for coarse crushing it is admitted that a type of machine must be adopted different from that best suited for fine crushing or grinding, there is not the same concurrence in the view which is nevertheless as indisputable, that the selection of the particular individual from the class of grinding or granulating machinery, should be determined by the use to which it is to be put, and the condition in which the resulting product should be delivered.



VERTICAL SECTION OF A SCHRANZ MILL.

chines occupied an inferior rank when applied to the pulverisation of hard or tough substance its position would have been reversed when operating on brittle or soft material. There are many machines soliciting public favour, which are either so wrong in principle or faulty in construction, and for which their inventors make such extravagant claims, that most cautious engineers unhesitatingly reject them. But outside this category there are so many other machines, correct in construction and in mode of operation, offering to do the same work, but at such different speed of production and expenditure of power, that no amateur should venture to choose for himself. No engineer feels safe in



A 10-STAMP BATTERY BUILT BY THE SANDYCROFT FOUNDRY & ENGINE WORKS CO., LTD., CHESTER, ENGLAND.

accepting the statistics of the manufacturer.

As a rule, most practical men, while admitting the palpable defects and the wastefulness of the older mechanical devices for crushing and pulverising, still resort to them, repelled by the innumerable and often irreparable disappointments, which have followed the adoption of a new invention. In the long run the practical man is wise. New inventions, whether in processes or machinery, can be safely introduced, only when paid for out of profits.

CAR FERRYING ON AMERICAN LAKES.

By A. S. Chapman.

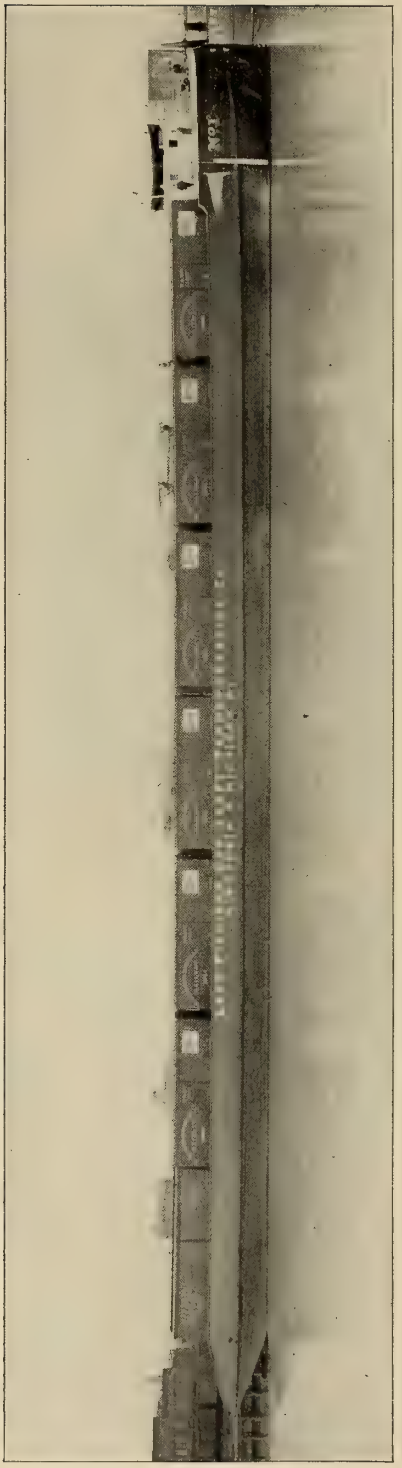
IN making the trip from Chicago to the head of Lake Michigan by steamer, the passengers may be startled by the sight of what appears to be a small railroad switching yard on the surface of the water. Striking as is the spectacle of long lines of freight cars in midlake, it is nevertheless unmistakable. On a nearer approach, it will be seen that the cars have their resting place on the deck of a huge boat, which is in tow of a small, but powerful steamer.

From the ferrying of cars across a river to ferrying them two-thirds of the length of Lake Michigan is a long step, yet this is the bold undertaking of the company whose boats are seen by the passengers. In 1892, the experiment was tried of transporting cars across Lake Michigan from Kewaunee, Wis., to Frankfort, Mich., as a part of a railroad system. No new principle was involved, but the feasibility of transferring cars for long distances by boat was demonstrated. The success of this experiment led to the evolution of an original and interesting theory of transportation.

In former systems of railroad economy, a car ferry had been regarded as a necessary nuisance, an expedient for bridging a gap of water, a connecting link between two lines of railroad. In the present system, the positions are reversed; the railroad upon land becomes subordinate to the water line, and we have the innovation of a railroad whose bed is the waves of Lake Michigan, whose locomotives are steamers, whose cars are towboats, and whose freight is cars. In the words of General Manager J. N. Faithorn, of the Lake Michigan Car Ferry Transportation Company, of Chicago, "this car ferry is not designed as a connecting link between two lines of railroad, nor as a terminal or transfer, but as a direct competitor for the business of railroads on their own terms."

The conclusion of the company that freight may be carried at a profit in this manner has been reached by a series of logical steps. The initial expense for towboats, transports and docks is but a fraction of the cost of equipment of a railroad on land of the same length. Neither are there any fixed charges of interest on bonds, nor any maintenance of right of way, with its corps of engineers, section men, switchmen or other employees. There is little wear and tear on rolling stock, and there are no machine shops to keep up. The cost of repairs is reduced to a minimum. Few men comparatively are required to operate this marine railroad. Most of the dangers of land railroads are eliminated, and there are other compensating advantages.

Nor is the working of the theory confined to the operating department. By studying the classifications of freight carried by water and rail, the promoters of the car ferry arrived at a natural division of the freight traffic:—first, the large volume of heavy and bulky materials, shipped by rail on account of the difficulty of loading and handling upon boats; second, such commodities as grain, coal, lumber and ore, which are carried at a low rate by water, with high



A CAR FLOAT OF THE LAKE MICHIGAN CAR FERRY TRANSPORTATION COMPANY.

charges for loading, unloading and handling. Much heavy freight, such as threshing machines, boilers and engines and the like, whose weight would naturally make them lake shipments, go actually by rail, from the expense and delay incident to stowing them in the holds of vessels.

In the case of grain, lumber and coal, while the carrying rate itself is low, the cost of loading and unloading bring transportation to a high figure. Take the single item of lumber! A car of lumber from the Wisconsin pineries arrives at a Lake Michigan port. The lumber is unloaded and piled on the deck of a schooner for shipment to South Chicago and thence East. Arrived at South Chicago, it is unloaded and again loaded into a car, with delays for switching and making up of trains

If now the load of lumber, on arriving in the Lake Michigan port, could be run upon the deck of a boat without breaking bulk, carried bodily to South Chicago and there made up into a train for the East, the expense of four handlings would be wiped out and a corresponding economy effected. If, then, carloads of coal from Indiana and Illinois could be run upon the boat for the return trip, another economy would be accomplished.

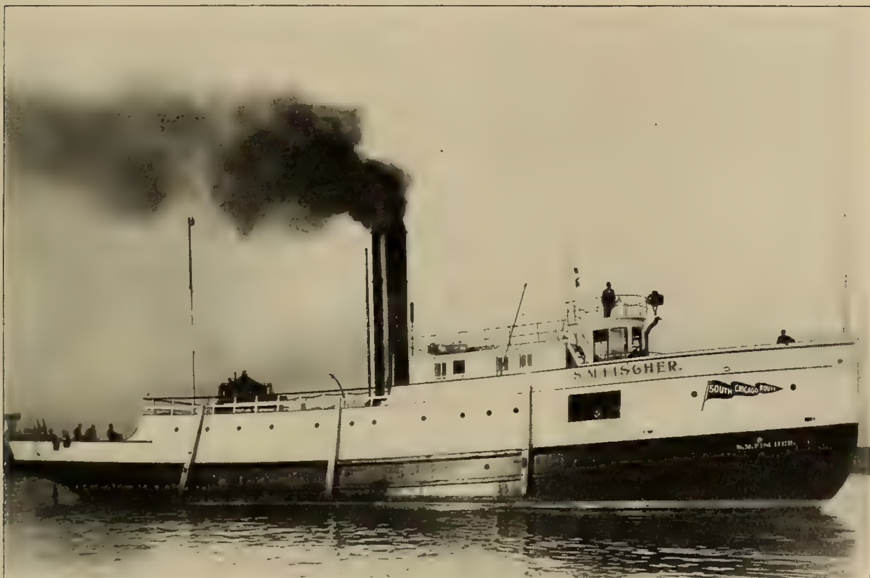
In the same manner, the enormous shipments of ore from the mines of Minnesota and Michigan are made from docks built and maintained at a vast expense, at which the cost of handling a ton of ore is at least 10 cents. The water rate to Lake Erie ports and the charges for unloading may be counted upon to bring the total expense to 69 cents a ton. Could the cars from the mines be run directly upon transport boats, the cost of twice handling would be avoided, the ore would be transported at a lower rate, and a fair profit would still remain.

In order to secure the benefits of the lowest rates, shipments must be made in the big lake freighters, whose draught of water is fourteen or sixteen feet, a fact that precludes them from entering any but the largest harbours. The car transports, however, are navigable in

seven feet of water, and are able to enter most of the smaller ports along the lake shore. In brief, the Lake Michigan car ferry is an attempt to combine the carrying capacity of the freight steamer with the facility of the freight car for handling all classes of business; to wipe out the heavy charges involved in the frequent handling of commodities, and to utilise the natural highway offered by the lake.

Not only is a gain in cheapness over the all-rail routes claimed for the car ferries, but a saving in time. Their northern terminus is at Pestigo Harbour, on the north shore of Green Bay, where it connects with the Wisconsin and Michigan Railway, an affiliated line running north to the "Soo" Railroad about fifty miles. From Pestigo Harbour to South Chicago, the southern terminus, the distance is 240 miles. The schedule time for a boat loaded with twenty-eight cars is twenty-three to twenty-four hours; two boats in the tow of one steamer make about eight miles an hour. When the speed of the average freight train is remembered, with the time taken up in stopping for junction points and in transferring around the belt lines in Chicago, the claims of the car ferry managers of a gain in time seem entitled to consideration.

The transports are 324 feet in length and forty-six feet beam. Twenty-eight cars of ordinary length make a load, in the aggregate about 1500 tons. In general appearance, without their deck loads, the transports resemble nothing so much as huge canal boats. In loading and unloading, a dock of special construction is, of course, necessary. The railroad tracks run from the shore upon a huge apron, from which the cars are shunted to the deck. Once in position, each car is carefully secured against the possible effects of rough weather.



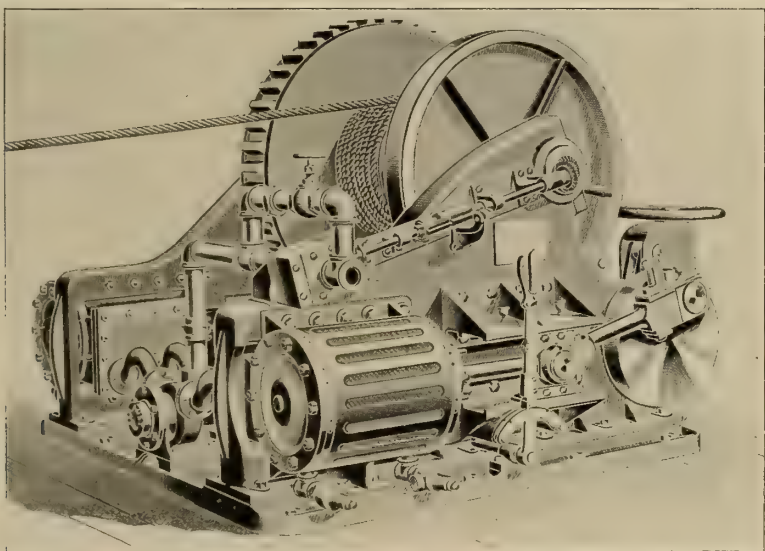
A CAR FERRY TOWING STEAMER ON LAKE MICHIGAN.

To solve the problem of towing a mass like a loaded transport through heavy seas, special devices were found necessary. At the bow of each transport is fastened a large chock, weighing several tons, through which, between a pair of great wheels, the cable to the steamer passes. From the chock, the cable passes along the deck to what is known as a towing machine. Roughly

THE CAR FERRY STEAMER "PÈRE MARQUETTE" AT THE DOCK, LOADING.

speaking, this is like the hoisting machine of an elevator. Not only does it take up the slack of the cable, but, in the case of a sudden strain, it acts as a steam cushion.

The illustration on this page will serve to give a good idea of one of these Shaw and Spiegle machines. A wire hawser is wound on a drum that is driven by a pinion gear on the crank shaft of the engines, which meshes with the gear on the drum shaft. A regulating, reducing steam valve is fitted to the engines, and in this valve the degree of opening is increased or diminished, according as the strain on the hawser increases or diminishes. In a seaway, as the vessel pays off, thus increasing the strain on the hawser, the drum begins to revolve and to pay out the hawser. This action opens the regulating valve and increases the steam pressure in the cylinders until the pressure is sufficient to equal the strain. Then if the strain decreases on the hawser the pressure in the cylinders will revolve the drum and wind in the hawser. In this way the machine is prevented from paying out the whole of the hawser, and only enough is paid out to relieve the extra and momentary strain on it, and thus prevent its injury or breaking. Incidentally, it may be stated here that towing machines of this type are coming into wider use every year, and are generally admitted to have solved a very important problem in towing operations. They are now in service, for example, with the Bessemer Steamship Company of Cleveland, who have nine; the Philadelphia and Reading Transportation Line, who have five; John Corrigan of Cleveland, with four; and the Standard Oil Company of New York, who have three, not to mention a host of others.



A SHAW AND SPIEGLE STEAM TOWING MACHINE, BUILT BY THE AMERICAN SHIP WINDLASS COMPANY, PROVIDENCE, R. I.

The steamer and its two transports form an impressive spectacle, suggestive of a marine caravan. The length of cable between the boats is 1200 feet, and the steamer, the cables, and the transports stretch out to a distance of nearly two-thirds of a mile. A crew of fifteen men is carried on each of the steamers and of six on the transports. The only present means of communication between the boats is a code of whistles, but a telephone system may be devised.

The ferry line from Pestigo Harbour to South Chicago was opened for traffic

THE CAR FERRY STEAMER "PÈRE MARQUETTE" ENTERING THE HARBOUR AT MANITOWOC, WIS. BUILT BY MESSRS. F. W. WHEELER & CO., WEST BAY CITY, MICH.

in September, 1895. No attempt at winter navigation in the accepted sense has been made, as ice forms in Green Bay early in the winter, and the company's towboats are not fitted for breaking their way through it. At some future time, an attempt may be made to keep a channel open by running tugs back and forth, but under present conditions, winter navigation is considered too costly and dangerous. No trouble has been experienced by the crews of the transports in weathering the heavy gales that sweep over Lake Michigan at times.

The latest addition to the car ferrying fleet on Lake Michigan is the steamer *Père Marquette*, which has been put into service between Ludington, Mich., and Manitowoc, Wis., by the Flint and Père Marquette Railroad, giving the Michigan railroad a connection with the lines along the west shore of the lake. The *Père Marquette* is built to transport passenger coaches and passengers, as well as freight cars. It has the important difference, too, as compared with the transports of the Lake Michigan Car Ferrying Company, of carrying the cars within itself, and not upon the deck. If the line of transports is imposing in length, the *Père Marquette* has the counterdistinction of size and impressive outlines. With her long and shapely hull, floating high in the water, and her pilot house, cabins and great smoke stacks, it requires but a slight effort of the imagination necessary to see in her a liner afloat on an inland ocean.

Thirty freight cars of standard size can be stowed in the space between her decks. Her length is 350 feet, and her beam 56 feet. Her engines of 3500 horse-power and her twin screws are calculated to give her a speed of from fifteen to sixteen miles an hour. Her displacement is 4050 tons, and her draught slightly over seventeen feet.

Wherever possible, the art of the shipbuilder has insured strength with beams, stanchions and channel irons, for the *Père Marquette* is not only to sail the summer seas, but to dare the Ice King in his own domain. So successfully has she been able to plow her way through the ice that she is said to have a speed of ten miles an hour through 14-inch ice.

The *Père Marquette* was put into service between Ludington and Manitowoc in February, 1897, and her service has been so successful that other ferries on the same lines will probably be built by the same company.

INVENTING FOR A LIVING.

By George Ethelbert Walsh.

IF it be true that originality is lacking in modern literature, may it not be assumed that the inventive spirit of the age has drawn the great creative minds into materialistic channels, where both the pecuniary and honorary rewards are more ample and secure? It is not belittling to the man of genius (or women, either) to seek the highest expression of his creative gifts in the field of scientific invention instead of in the drama, the poem, or the essay. The invisible world of magic and wonderland is open to the inventor whose imagination is stimulated by rightly balanced creative faculties. The world of fancy and fiction contains no more animating and beautiful pictures to enthrall the human mind and incite the passions. The storehouse of Nature's secrets is a veritable paradise of elusive, but suggestive, ideas that can be grasped only by the highest type of mind—the creative, imaginative intellect. Lesser lights may stumble upon inventions that will revolutionise one phase of our daily life; but the great world-reaching discoveries of science have been the outcome of intense application of great minds—of geniuses that might have written immortal poems or dramas.

There is something more tangible to the public in the invention of a labour-saving machine than in a written poem or essay. The delicate and refined art of a literary masterpiece is appreciated only by the few; but the telegraph, phonograph, electric dynamo, and steam engine appeal to all—even to the budding children of our generation. The inventor is not entirely indifferent to the rewards of success which make his name a household word; the greatest minds find a quiet satisfaction in seeing the results of their work appreciated by the multitude. In the pursuit of his elusive ideas, which he would shape in some tangible form, the inventor must be something of a poet and student; a poet in conceiving forms that do not exist except in his imagination, and a student in working out the details in the light of past knowledge and experience. Without a sublime imagination to see the hidden powers of nature, and read in little things the reign of universal law, the lightning would never have been chained to do our will, the air waves would not have been collected to repeat the human voice, nor the sun's rays utilised for printing images of material objects around us. The accidental part of great inventions has been, after all, merely incidental to the chief aim; study and a cultivated imagination preceded and prepared the mind for the so-called accident—the sudden dawning upon the mind of the whole truth.

Prominent inventors, who have earned their reputation by repeated discoveries, and who are entitled to speak authoritatively, attribute their success to hard study and experiment. The idea of an invention breaks in upon the mind often so suddenly, or it is suggested so forcibly by some ordinary article or event, that it is natural to claim for it an accidental birth; but the untrained mind would never have seen the connection, nor grasped the truth. There are heaven-born geniuses in the world of invention, as in the realm of letters, to whom concepts and expression come by

intuition; but the former even more than the latter would be inclined to define genius ordinarily as the capacity for hard and long-sustained work.

The inventors of the present century have created an entirely new world for us; we hardly recognise the existence of untamed nature; we are so accustomed to see her powers and forces chained and harnessed to obey our will that we are startled when our minds try to conceive the condition of our ancestors. And each year and decade this swift revolution brings another world into existence for us; we drop our old habiliments so rapidly that our minds get bewildered. The pace is swift and enervating at times; but we must keep up with it. We master the latest achievement with great difficulty, and heave a sigh of relief at the accomplishment; but we wake up to find that it is already antiquated, and that we must begin all over again to adjust ourselves to the changes. An Edison, a Tesla, a Thomson, or a Howe is labouring diligently in the field ahead of us, always beckoning us onward, knowing that we can never catch up to them, or barely comprehend their brilliant ideas, until they have become second-hand material to them.

The tidal wave of inventions that has nearly swamped the ordinary intellects trying to keep pace with it began fifty years ago in a small, insignificant ripple. There were obstacles in the way to impede the flow of the wave. Financial depressions brought disaster to the inventive spirit of the age more than once; but through the vista of the years we can now see the gradual rise and overflow of the mounting wave, deflected, depressed, and shattered at times, but always gaining ground and momentum. At the opening of the new chapter of progress Professor Morse had just completed his system of electro-magnetic telegraph, which gave an impetus to inventions that has scarcely been equalled by any subsequent discovery, and which finally ended by girdling the globe with cables and telegraph wires so that it has shrunk to one-thousandth part of its former self. The dormant geniuses of the age awakened to the possibilities of the world of invention, and within ten years after 1845 gave to the world the terrible explosive, nitro-glycerine, the first sewing-machine, the printing telegraph, the McCormick reaper, the Corliss engine, the Ruhmkorff coil, the duplex telegraph, Ericsson's hot-air engine, and numerous other inventions of equal and minor importance.

Having gained accelerated motion, the tidal wave expanded, reaching out into every department of human endeavour. Men of genius and practical experience saw the possibilities of great reward in inventions, and many devoted their lives to the discovery of useful articles. The laying of the Atlantic cable emphasised the spirit of the age. Then the breaking out of the American Civil War stopped the tide temporarily, or rather deflected it into another channel. In the quietness of his laboratory the scientist had discovered caesium, rubidium, indium, and thaldium, and in the mill and factory the practical workers had discovered coal oil, the aniline dyes, and wood-pulp paper. But the mechanic turned his attention to the invention of warlike implements. Ericsson's monitor came forth from its simple ship-yard and revolutionised ship building; Whitehead injected his torpedo into the turmoil of battling navies, and Noble added his terrible explosive gelatine to the deadly weapons in the hands of contending nations.

Later, the inventive world was enriched by such geniuses as Siemens, Wheatstone, Brush, Weston, Wilde, Edison, Varley, Pasteur, Janney, Thomson, Gramme, Farmer, Hallidie, and Lowe. The dynamo and electric motor neared perfection; air-brakes and air-rock drills came to improve the railroad service and mining industry; the first cable cars appeared in cities; and innumerable improvements were made in the machinery of mills and factories.

The tidal wave of invention was now in full sweep again, and nothing has been done to obstruct its onward march, or to deflect it from its original course, and it carries to-day on its crest such a

multitude of inventions and promises and speculations that the mind is fairly staggered.

Liberal treatment of the inventor, and a careful watchfulness for the interests of the public, have been the means of stimulating the mechanical genius of nations. The love for his work, and the glory that may redound to his name, are, however, hardly sufficient rewards for the inventor to labour assiduously in his chosen field, and if the certainty of pecuniary returns were questioned, the age would not be so prolific of labour-saving inventions. When money is the most direct means to a life of study, refinement, and pleasure, it will be an important consideration in directing and stimulating talent and genius in every department of modern existence—not even excepting that of art, music, and literature. It may be a decadent view of life; but the facts can hardly be gainsaid. The genius, who towers above money considerations, and disdains to stoop from his high pedestal, is almost an extinct creature.

The craze for inventing has permeated every class of society, and with the rich promises of money returns the number of recruits is annually increased with startling rapidity. If it be true, as many assert, that there is hardly a village or country hamlet where literary aspirants cannot be found in numbers, while the larger towns and cities are crowded with them, the country would seem to be going literary-mad; but there are even more inventors and would-be inventors than budding poets and novelists, and yet their numbers are not oppressively burdensome. In every walk of life there are people who carry in their heads a vague idea of some invention that they will some day patent, and then make their fortune. The majority of these crude ideas never take definite form; a good proportion of the balance die in the vain attempt to make a working model; and another fair percentage is rejected by the Patent Office. Of the comparatively few which pass final inspection, only a limited number ever make the fortunes of their owners. Some, like ordinary novels and books of poems, do not pay for the expense of putting them on the market; others bring in a small sum in the course of a year or two; and the favoured few make their inventors wealthy—often beyond all conception.

It is of these few that the public talk and by which they gauge the value of all patents. If a man makes his hundreds of thousands by the invention of a collar clasp, or a peculiar style of button, why should not another reap his millions through the invention of a complicated piece of machinery? This reasoning is not justified in the light of past experience. Often the smallest trifle of an invention has been more remunerative than the most laboured and complicated mechanism of a steam engine or electrical apparatus. The importance of the general use and demand of an article is the true measure of the money value of an invention.

It has become almost an axiom with the majority that larger fortunes are to be realised from some simple invention than from difficult and expensive inventions that involve a great outlay of money to manufacture. This is to a certain extent true. A certain American patent for fastening kid gloves has yielded a fortune of several hundred thousand dollars for its fortunate owner, and the inventor of a collar clasp enjoys $20,000 royalty a year as the reward for his endeavour. A new kind of sleeve button has made $50,000 in five years for its patentee, and the simple twisting of safety pins in such a way that there is no possible danger of the point sticking in the child promises to enrich its owner beyond any of his early dreams of wealth. A man one day turned a piece of wire so as to hold a cork more securely in a bottle, and forthwith somebody saw a brilliant idea, and patented the modern wire stopple-holder, which is now used annually on several million bottles. The accidental bending of a hairpin by a woman to prevent it from sliding out of her hair so easily produced a fortune for her husband, who immediately saw the possibilities of a crinkled hairpin for women.

Instances could be multiplied indefi-

sitely of large fortunes being made from nmall inventions; but fortunately for those inventors who make a life study of intricate problems of mechanics, and disdain to waste their talents upon trivial popular articles of the day, there is often also ample reward held in store for the products that take years to produce, and which revolutionise existing methods of industry and mechanics. Edison has reaped honours and riches of a princely character from his discoveries; McCormick has realised in his reaper the fortunes of a millionaire; the Corliss engine brought honours and decorations to its inventor, and enabled him to amass a great fortune in a few years; Professor Bell found in his telephone not only the consummation of his early hopes and ambitions, but a substantial pecuniary reward; Harveyised steel armour has become synonymous with the inventor's name, and it brings an annual income of huge proportions to its discoverer; Elias Howe, the inventor of the sewing-machine, realised over $2,000,000 from his inventions; and Nikola Tesla, though still young and rich in promises, finds an abundance of money in his work.

Rarely has the inventor in recent years suffered from lack of funds when his discovery has been of genuine value. The few exceptions merely go to prove the old rule, and in most cases they were due to fortuitous circumstances that have little bearing upon the point in question. There are probably richer rewards open to the inventor to-day than to almost any other class. With every new innovation corresponding disadvantages are invited, which need further invention to correct; and the more complex our lives grow, the more important are the needs of new devices, new discoveries, and new luxuries. What satisfies one age hardly comes up to the requirements of the next. The field for the inventor is thus ever broadening and developing, and the possibilities of his amassing a fortune from his discoveries grow apace with the need of his products.

ACROSS THE CHILKOOT PASS BY WIRE CABLE.

By William Hewitt.

THE stories that come from the Klondike are almost incredible, and yet they are amply verified by the amount of gold brought back by returned miners, and recent advices from Alaska state that the rush for that section has already fairly set in. The question of transportation, therefore, has become one of paramount importance, and already several transportation lines by vessel have been established, and routes surveyed for projected railways.

The water route by way of St. Michaels and the Yukon river is the one thus far generally preferred, as it is attended with less hardships perhaps than any other. But as this will scarcely be open before next June or July, the bulk of the travel at first will be by way of Dyea and Lake Lindeman, across the Chilkoot Pass, and travellers going this way will experience the novel sensation of a trip through the air over the more mountainous portion of the route. It is not to be surmised from this that the trip will be made by balloon. Not yet! While it is not at all improbable that the free navigation of the air may some day become a practicable thing, this fond hope of aeronauts has not yet been realised. The passage will be made by a line of overhead wire cables,—an aerial tramway, which is perhaps the nearest approach to aerial navigation that has yet been made.

Few perhaps are aware of the extent to which this method has been applied, especially in mountainous sections, where a surface road of any kind would be practicable only by long and expensive detours, or might be altogether impracticable. The adoption of this method of transportation for surmounting the terrors of the Chilkoot Pass and opening a pathway to the Klondike has brought the subject into considerable prominence, and it will be of interest, therefore, to present some of the more salient features of the Bleichert system, which has been adopted by the Chilkoot Railroad and Transport Company for this purpose.

The inception of this enterprise dates from the early part of last September, when a party of surveyors, under the direction of A. McL. Hawks, of Tacoma, Wash., U. S. A., made a complete topographical survey of the ground, and determined the most feasible route for the proposed tramway. The intention at first was to use the cable system for covering only the mountainous portion of the route from Sheep Camp to Crater Lake, a distance of 3½ miles, and a contract was made for such a line; but since then, owing to the difficulties of laying a surface road to Sheep Camp, it has been decided to extend the cable line 3½ miles towards Dyea, to a point known as Canyon Camp, where connection is made with a surface road, running through the Dyea Canyon, and along the Dyea river, to the head of tidewater, thus making an uninterrupted line of transportation between Dyea and Crater Lake. Later on, the cable system will, undoubtedly, be extended to Lake Lindeman, the head of lake navigation.

The first section of the cable tramway from Canyon Camp to Sheep Camp is now completed, and the re-

maining part of the work is being pushed as rapidly as possible. Although such lines have been used to a limited extent as a means of conveyance by miners in going to and from their work, they have heretofore been designed more especially for carrying ores and other similar freight, and the Chilkoot tramway is the first one designed with a view to passenger traffic.

The idea of transportation by receptacles suspended from a wire cable may seem, at first glance, simply an extended application, on a large scale, of the mechanism involved in the wire cash carriers used in many modern American department stores; yet experience has demonstrated, as it has in most other undertakings on a large scale, that many things must be taken into account to ensure their successful operation, and it has been just this experience, added to years of careful study of every detail, that the present high standard of excellence in equipments of this kind has been reached.

The buckets, or other receptacles, in the Bleichert system are suspended from carriages which run on stationary cables, and are moved by a light endless rope, known as the traction rope, to which they are attached, and which travels continuously about terminal sheaves. This is the general distinguishing feature of the system and has led to its being known in many localities as the "double rope" or "fixed rope" system, in contradistinction to the "single rope" system, in which one rope performs both functions.

THE CABLEWAY TERMINAL AT SHEEP CAMP, THE ENTRANCE TO CHILKOOT PASS.

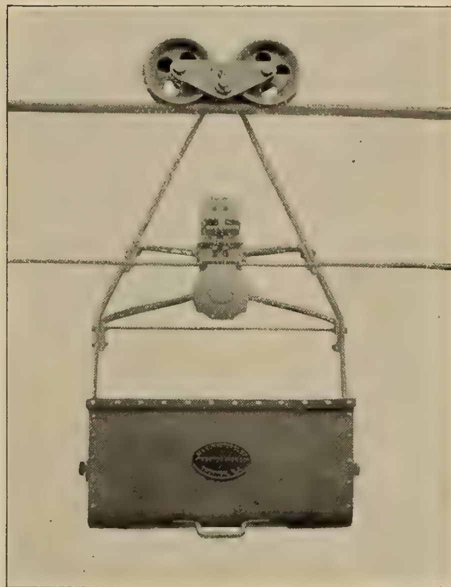
It is a curious fact that the pioneer in this field, Mr. Charles Hodgson, of Richmond, England, first directed his attention to the "double rope" system, and his earliest experiments were in this direction; but he appears to have abandoned it soon after he began to develop his inventions, doubtless on account of the difficulties encountered in procuring the kind of cables and materials suitable for the construction of the rolling stock and operating parts that this system demanded. Steel castings,

and the high grades of tempered steel-wire now used in the construction of the best cables, were then unknown; everything had to be of cast or wrought iron, and this was a serious drawback to the earlier wire rope tramways, which, in consequence, were comparatively crude and clumsy affairs.

The advent of steel cables and steel castings, however, led to the development of the "double rope" system at the hands of Mr. Adolf Bleichert, of Leipzig-Gohlis, Germany, who brought to bear on the subject the skill of engineering talent, added to the ingenuity of an inventive genius. The development of the Bleichert system has been carried on still further by the manufacturers in the United States,—the Trenton Iron Company, of Trenton, N. J.—who introduced several improvements, more especially in the construction of the track cables and the grips for attaching the cars to the moving rope, and the success and increasing popularity of this method of transportation are due in a large measure to these improvements.

The track cables are of peculiar construction, and are known as "locked-coil" cable, from the fact that the outer wires are of such shape that they interlock with each other, as shown in the accompanying illustration, presenting a smooth surface, and yet possessing sufficient flexibility to be shipped in coils. These cables are made in lengths of from 800 to 2400 feet, which are joined by special couplings. These are made in halves, each of which embraces a funnel-shaped aperture, into which the ends of the cables are socketed, the two halves being joined by a plug with right and left-hand screw threads.

The objection to ordinary cables, or ropes composed of strands, each of which is made up of a number of round wires, twisted about a central strand or



ONE OF THE ROPEWAY CARS FITTED WITH A WEBBER COMPRESSION GRIP.

core, is, that the wires soon break under the constant rolling of the small carriage wheels over them, resulting in a ragged and uneven surface, as shown in the upper part of the illustration on page 535. This is due to the fact that pressure at any instant is confined to a few wires over a comparatively narrow surface. The locked-coil cable, it will be observed, has a surface almost as smooth as a solid round bar, and this form of cable, therefore, not only renders the highest

A LOCKED-COIL TRACK CABLE.

CROSSING THE SUMMIT IN CHILKOOT PASS.

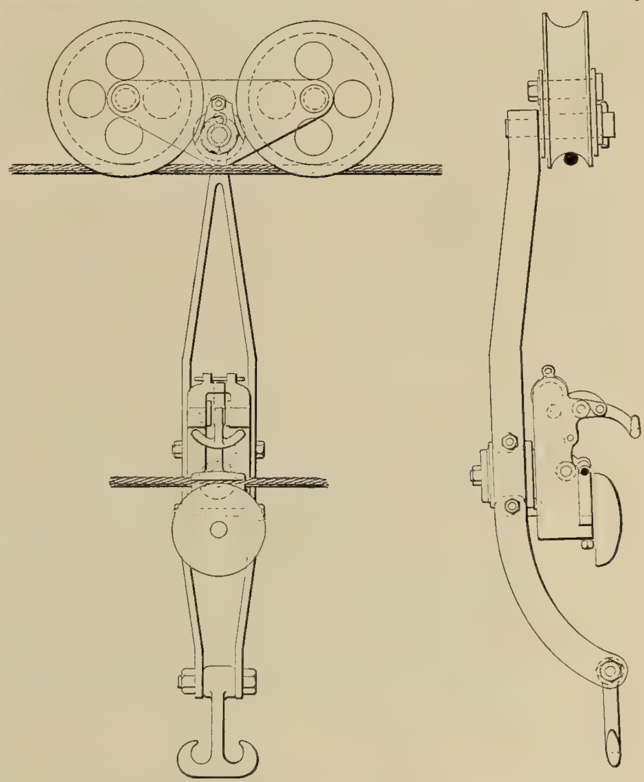
degree of service, but results in a minimum wear on the wheels of the carriages from which the loads are suspended.

In the case of the Chilkoot tramway, however, it was necessary to make everything as light as possible, consistent with the necessary strength, owing to excessive transportation charges, and it was found impracticable to use the locked-coil cables on account of the difficulty of making a cable of this kind as small as the exigencies of the case demanded. A style of cable was therefore adopted known as the "smooth coil" cable, the kind first used for the track cables of Bleichert tramways. This cable is composed of a series of round wires, considerably larger than the wires of ordinary wire ropes or cables, and laid up in the manner of a single strand. The cables of the Chilcoot tramway are but ⅝ of an inch in diameter, and weigh about 7-10 of a pound to the foot. The wires are of a special grade of crucible steel known as "plough steel," possessing a tensile strength far greater than the steel ordinarily used, the finished cable having an ultimate strength of 36,000 pounds.

The "smooth coil" cable, while superior to ordinary wire rope as a track cable, obviated only in a degree the objections to the ordinary rope, and possessed the further disadvantage that when a wire did break, it was liable to strip or uncoil for a considerable distance. Several devices have been resorted to for holding the loose ends of such wires in place, but the best of them have given but indifferent satisfaction. It is rare, however, for the wires to break under a reasonable degree of service, and the illustration on page 535 of a rope of this kind, after it had been in use day and night for a period of over four years, shows what may be expected of such a cable, and what it looks like when worn.

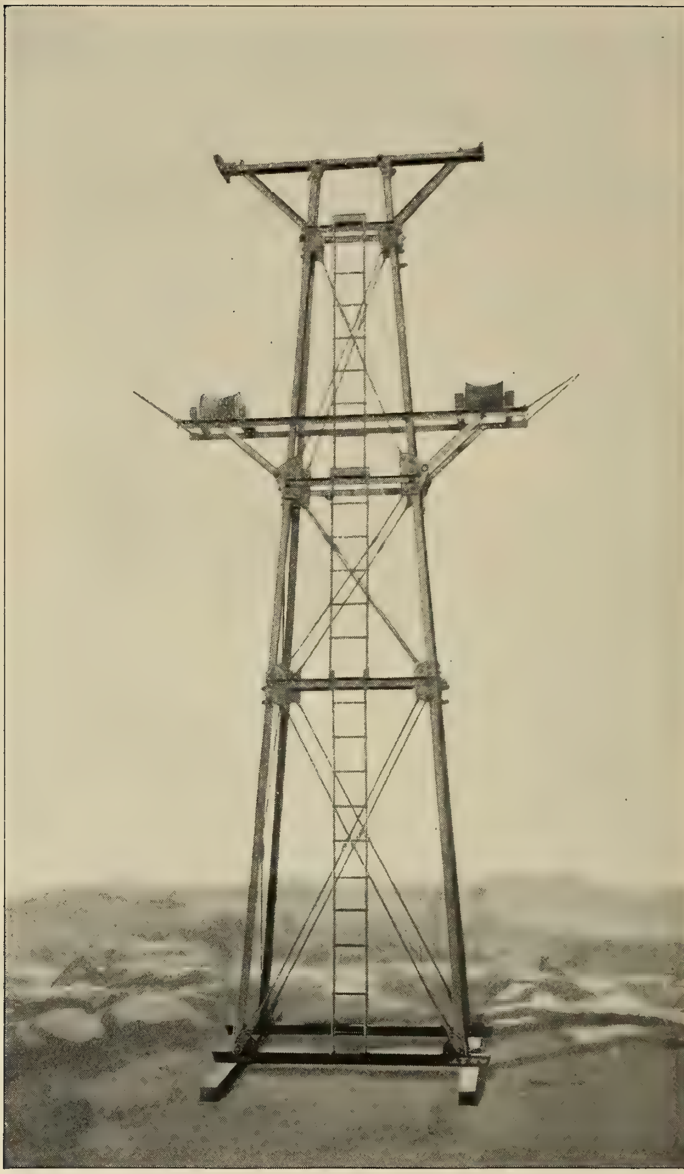
A CABLE COUPLING.

The locked-coil cables are made in sizes from ⅞ inches up to 1½ inches in diameter, ranging in weight from 2 to 5½ pounds to the foot. Loads of a ton may be carried on a 1½-inch cable; but, as a rule, it is not desirable to carry such heavy weights, and for a given output the loads will be regulated according to the number of cars that a man can despatch in a given time to the best advantage. This will determine also the proper sizes of cables to use. The intervals will vary from a car every minute to a car every half minute, according to the desired output; on some lines the cars are despatched as often as one every 20 seconds. The usual load for outputs up to 20 or even 25 tons per hour, is from 400 to 600 pounds, according to the nature of the material, and for outputs above this, 1000 to 1500 pounds.



CABLEWAY CARRIER AND FRICTION GRIP DETAILS

A further advantage in the use of stationary track cables is due to the high tension to which these cables may be stretched, which results in a comparatively direct path for the moving loads, and a uniform motion, whereas in "single rope" lines, in order to avoid overstraining the rope, the dual function it has to perform in both supporting and moving the loads neces-



A FORM OF IRON TOWER SUPPORT WHICH COULD NOT, HOWEVER, BE USED IN CHILKOOT PASS BECAUSE OF TRANSPORTATION DIFFICULTIES.

sarily results in greater deflections between the supports, and consequently more vertical movement, or wave motion, for which reason also the speed of such lines cannot be as great as in lines of the "double-rope" type. In the latter type of tramways also, the weight of the loads is shared to a certain extent by both the track cables and the traction rope. On level lines, most of the weight is borne by the track cables, and the stress on the traction rope, therefore, is little more than the tractive force required to move the loads. Upon slopes, however, the stress upon each will vary according to the inclina-

tion; the steeper this is, the greater the stress in the traction rope, and the less that in the track cable, and *vice versa.* It is evident from this that an accurate profile of the ground is essential in laying out any line.

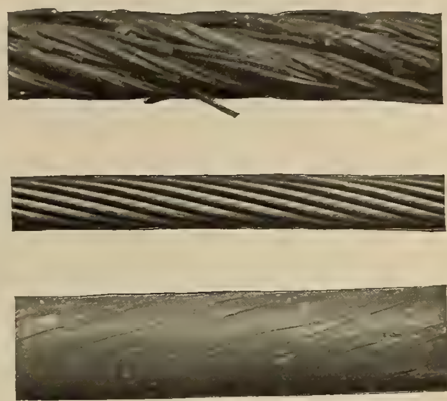
The usual practice is to lay out the line of the track cables for a safe working tension, and erect the supports to this line, the cables being weighted to a somewhat lower tension, so that there may be no possibility of their rising out of the saddles upon which they rest. Where the cable lines pass at a considerable elevation above the ground, or at such an elevation that the deflection due to the weight of the moving loads would not cause the buckets to strike or interfere with objects below, it is not absolutely necessary to put in supports. The supporting points, therefore, will be located mostly on the ridges and more elevated portions of the route.

In the Chilkoot line, there is one clear span of 1600 feet, and another span only slightly shorter. There are a couple of lines near Silverton, in Colorado, each of which contains a clear span of 2100 feet, and

A USUAL FORM OF TIMBER SUPPORT.

these lines have been in satisfactory operation for several years. A view is given on page 536 of the tramway of the Bunker Hill and Sullivan Mining and Concentrating Company, showing a clear span of 1173 feet, where the line crosses the town of Wardner, in Idaho, U. S. A.

In most lines the tension in the track



1.—ORDINARY WIRE ROPE, WORN FROM USE.
2.—A NEW SMOOTH-COIL TRACK CABLE.
3.—SMOOTH-COIL TRACK CABLE AFTER FOUR YEARS' USE.

cables is produced by weights applied at one or the other of the terminal stations; but in lines of great length it becomes necessary, on account of the saddle friction, to apply tension at intermediate points also, the location of which will vary from 3000 to 6000 feet apart, according to the contour of the ground, the points usually selected being on the side of a hill, or on some level portion of the ground. The track cables are parted at these points, the ends of the upper section of the line being counterweighted, and the ends of the lower section being firmly anchored. The cars pass from one section of the cable to the next by means of intervening rails, so that no interruption occurs in the continuity of the track. The structures at such points are known as tension stations. Occasionally such a station will happen in a valley or ravine, in which case the cable ends of both sections of the line are counterweighted,

WIRE ROPE TRAMWAY OF THE BUNKER HILL AND SULLIVAN MINING AND CONCENTRATING COMPANY AT KELLOG, IDAHO, U. S. A., ILLUSTRATING LONG-SPAN CONSTRUCTION. THE SPAN IN THIS CASE IS 1173 FEET, AND EXTENDS ACROSS THE TOWN OF WARDNER.

or it may happen to be desirable to locate such a station on an elevated point, in which case both ends are anchored. In any event, one end of any section is always weighted and the other anchored. Where the line crosses a sharp ridge, supporting structures are frequently used and are known as rail stations. These consist of a series of bents from 15 to 20 feet apart, supporting steel rails, which overlie the track cables, and save them from undue wear.

Next in importance to the track cables is the rolling stock, and more especially the means employed for attaching the cars to the moving rope. Various styles of grips have been used, some depending simply on frictional contact for holding, and others again designed to straddle lugs clamped to the traction rope at certain intervals, or secured by pins. The latter style of grip has been employed mostly on lines in which steep grades occur, as the friction grips heretofore used could not be depended on in such cases. In some instances, instead of lugs, bulbous points have been produced in the rope, by inserting metallic pieces between the strands, known as star knots.

The car illustrated on page 531 shows the grip used on the Chilkoot tramway. This is the invention of Mr. S. S. Webber, assistant manager of the Trenton Iron Company, and is known as the Webber grip. The jaws of this grip are operated by a peculiar arrangement of toggle-jointed levers that produce a bite on the rope sufficient to hold securely on any grade. These grips have been applied on a great many lines in the past few years, some of them with grades as steep as 45 degrees. When properly adjusted these grips have never been known to slip. The advantages of such a grip are manifest, in distributing the wear over the entire rope, instead of confining it to certain spots, as is the case where lugs are used, and the life of the traction rope is thereby greatly

A WIRE ROPE TRAMWAY USED BY THE SOLVAY PROCESS COMPANY AT SYRACUSE, N. Y. THIS SHOWS BOTH WOODEN AND IRON SUPPORTS.

increased. A further objection to lugs, or knots of any kind, arises from the constant hammering which they receive. This loosens them in time, so that they slip, which has been not only a source of great annoyance, but in one or two instances has resulted in serious accidents. This occurs not only in despatching the cars, but also while they are in transit, at every change in the grade or irregularity in the motion of the rope. The Webber grip forms a direct and rigid bond between the car and the rope, and, like a bulldog, when it once takes hold, there is no shaking it off.

The view of the Chilkoot cableway on page 532 showing that portion of the line where it crosses the summit, illustrates the manner in which passengers will be carried. It is needless to say that all will travel alike; there will be no drawing room cars.

This view also illustrates the style of support used, which consists simply of one or more sections of iron pipe, bolted together and imbedded in the rock, and bearing cross timbers which support the saddles upon which the track cables rest, and the rollers also upon which the traction rope travels. The supports, as ordinarily constructed, are of various designs, and may be either wooden or iron structures, as preferred. The view on page 537, of the Solvay Process Company's line near Syracuse, N. Y., used for carrying lime rock from the Split Rock quarries to the soda ash works, at Geddes, a distance of about 3¼ miles, shows two supports, one of wood and the other of iron, of the tower type,—the style mostly used on lines of heavy outputs, and where long spans occur. All the supports of this line were originally of wood, but it is the intention of the company to replace these with iron supports as the wooden ones give out.

Other types consist simply of square frames, or more commonly of *A*-shaped frames braced against longitudinal pressure. On some lines, where snow-slides occur, the best type of support has been found by experience to consist of a single stick or mast imbedded in concrete and guyed by wire ropes. An illustration is also given on page 534 of an iron support of the ordinary tower construction, such as was adopted on a line on the island of Hayti nearly 12 miles in length, used for transporting logwood.

SUGGESTIONS FOR IMPROVEMENT IN POWER PLANTS.

By A. Bement.

IN designing steam plants for electric service, such as railway work, lighting, and power transmission generally, it is the usual practice to select the most efficient and economical engines that the conditions under which the installations are to be made will allow. Comparatively high efficiency is therefore obtained so far as the main units are concerned. But there are always a greater or less number of auxiliary machines, such as circulating, air, and feed pumps, coal and ash hoisting engines and air compressors, and while these develop a comparatively small percentage of the horse-power of the main engines, this power is often obtained by a most extravagant use of steam. This is a generally recognised fact. In some cases it may be safely stated that a steam pump will require twenty times the quantity of steam to produce a horse-power that an engine of the better class would use to deliver an equal amount of power.

This being the case, it would certainly result in greater efficiency of the whole plant if these auxiliaries could be made to perform their work with a steam consumption of a proportionate ratio to that of the main engines. To accomplish this result the writer would sug-

gest the use of pumps driven by electric motors, and the use of electric motors in place of small engines. In this way the efficiency of the main engines may be realised in these auxiliary machines, less the transmission loss, which is comparatively small. It may appear that this method would result in the auxiliaries being less independent and liable to interruption in the supply of the electric current; but when it is considered that a lighting or railway plant has always at least one unit in service, this objection cannot hold good, and especially not where storage batteries are installed.

This same scheme applies with equal force to other than electric plants, when the auxiliaries would be driven by the main engine direct, or from the shafting. It is true that means should be provided for the control of these power-driven auxiliaries, so that they may be as convenient as the usual steam-driven ones. This is, however, not a difficult engineering problem.

It is now the usual practice, in cases where the main engines exhaust into condensers, to utilise the exhaust steam from the auxiliary engines to heat the feed water, and this has, no doubt, contributed largely to maintain the strong position which the small steam apparatus has obtained, in face of the fact that in themselves these pumps and small engines are the most wasteful machines with which the engineer has to deal.

It is proposed, therefore, in condensing plants, that there shall be no exhaust steam, and consequently feed water will not be heated by steam. And in cases where engines are not operated in connection with a condenser, it is, in the writer's opinion, most advisable to seek such uses for the exhaust as warming rooms or buildings, boiling, drying, or many of the similar uses that are to be found to a greater or less extent in most works. If after such uses there be still exhaust steam available, it then could be used to heat feed water.

As it is proposed largely to do away with the heating of feed water by exhaust steam, and in many cases altogether, other means are required, and it is proposed to accomplish this by means of fuel economisers, composed of banks of cast iron tubes, located between the boilers and the chimney in such way that the gases of combustion, after leaving the boiler heating surface, shall act upon the economiser surface before entering the chimney.

Economisers have been extensively used for many years, especially in Great Britain, and to a limited extent in the older well-settled portions of the United States But it does not appear that they have been justly appreciated, or that their possibilities have been fully understood. In general, the economiser has been looked upon as an expensive luxury to be used to recover some of the heat units from the "waste" gases leaving the boilers. That any of the heat units, however, obtained at considerable expense, should be considered as waste product is simply the natural view resulting from crude practice. The position may be taken that instead of looking upon and treating the economiser as an auxiliary to a boiler plant, it should be considered as an important part of the steam generating apparatus.

The second or third cylinders of a compound or triple expansion engine are certainly considered as a part of the whole machine, and not as auxiliaries to utilise waste steam from the initial cylinder. As in the combination of cylinders, so with the combination of boilers and economisers,—both constitute an outfit to utilise temperatures at different stages, one in steam and the other in heated gases of combustion.

When economisers are used, the matter of draught to maintain proper combustion is a very important one. The draught required in such a case is considerably greater than when no economisers are used, and its production becomes a problem of special importance.

While the preponderance of opinion is in favour of the chimney as the most economical means of producing draft, whether economisers are used or not, this is a matter entitled to impartial examination. It is the writer's opinion

that the best mechanical draught methods have greater possibilities of economy and convenience than the best chimney has, and that draft produced by mechanical means makes it possible to reduce the temperature of the escaping gases to a point much below that which would otherwise be required.

As bearing on the relative cost of producing draft by mechanical means and by utilising an ascending column of heated gases in a chimney, it may be well to consider the statement of an eminent authority in speaking of experiments made to ascertain the relative costs of ventilating by means of a column of heated air, and by a fan driven by a steam engine. With a chimney 100 feet high, it was found that the cost of heating the necessary column of air was very many times greater than the cost of the steam for the fan engine, the amount of work being the same in both experiments, and the engine being a very ordinary one.

Current Topics.

The publicity that has been given during the past few months to a so-called felt mat for rails as a means of deadening the noise from passing trains, brings to mind one expedient which was adopted some years ago to overcome vibration from a steam engine in a building where quiet running was a particular desideratum. The engine had been giving considerable trouble, and as almost a last resort a layer of hair felt, an inch or more in thickness, was interposed between the bedplate and the stone capped foundation. The exact details of the arrangement are not clearly remembered at this time, but the impression prevails that the hair felt was confined in a kind of shallow pan, into which the bedplate fitted, and was thus prevented from working out sideways under the influence of the superimposed weight. The result was immediately satisfactory. The jar and tremble ceased, and what had promised to be an incurable evil disappeared as if by magic.

Apropos of the best kind of floor for a machine shop, which comes up for discussion periodically, a story is told of one superintendent who noticed a great difference in the apparent activity of two sets of men working on similar jobs at the vise in two rooms of a large shop, one being in an old building and the other in one of recent construction. In the former room the men stood easily and naturally at their work, and showed no symptoms of a hankering after a seat on the bench, while in the latter the men were shifting their weight from one

foot to the other, throwing one leg upon the bench at every opportunity and showing every evidence of foot fatigue. The difference was concluded to be due to the floors upon which the men were standing. In the old shop the floor was of wood, springy to a certain extent and a poor conductor of heat; in the new shop it was of concrete, an excellent conductor of heat from the foot of the workman and perfectly unyielding. The benches in the new shop were, therefore, raised a couple of inches, and each man received a platform of wood that rested on two cross pieces at the end and had a light spring to it. The foot weariness, it is said, disappeared almost at once and no further trouble was experienced.

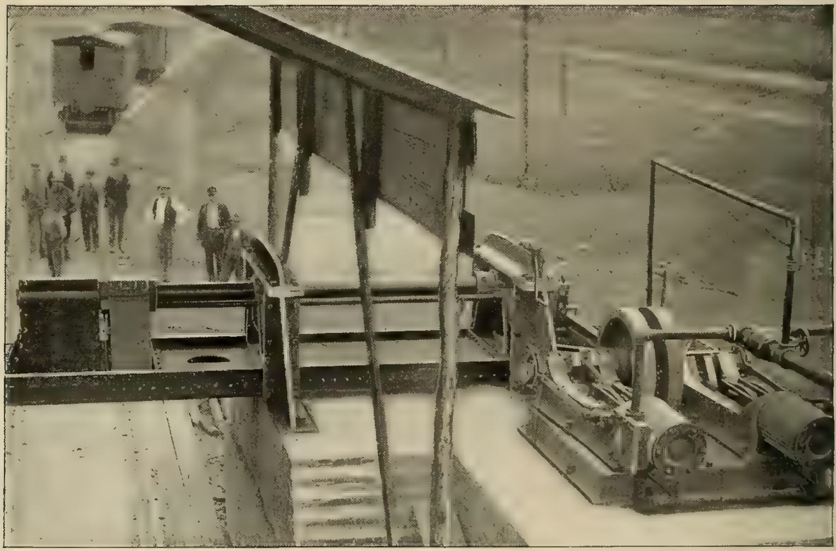
TRANSFERRING light goods and passengers' baggage from the depot at a large railway station to the various train platforms, or from one platform to another, is a problem which has always been fraught with perplexing difficulties. Mr. J. A. F. Aspinall, chief mechanical engineer of the Lancashire and Yorkshire Railway Company, however, some time ago put into operation at the Victoria Station, at Manchester, England, a suspended overhead tramway, in conjunction with a combined electric traveller and crane, which appears to have solved this problem in a very satisfactory manner. The general character of the equipment which he put in is shown in the little sketch on this page. It will be seen in this that the attendant travels with the apparatus, his seat being a broad strap and his legs being supported by two curved rests placed on either side of the electric motor. In this position he faces, and has control over the arrangement of "pulls" and "contacts" provided for performing the several operations required, such as movement forward, or backward, and the lifting, or lowering, of the load. The parcels and packages are placed in large baskets which are mounted on a set of small wheels, to allow of their being readily moved about the ground or platform. Shackles are provided on these baskets to which the tackle attached to the traveller can be rapidly hooked and disengaged. The rails on which the traveller runs act as the supply and return conductors for the cur-

OVERHEAD ELECTRIC CRANE AND TRAVELLER AT THE VICTORIA STATION, MANCHESTER, ENGLAND.

rent, being properly insulated from their supports. The motor is worked from a 100 to 110-volt circuit, and the speed of travelling along the tramway is about 700 feet per minute. During the two years that the apparatus has been in operation it has been found that the traveller runs about 100 miles a week, making about 500 double journeys. The class of work which it is performing suggests other applications of the system. In warehouses and on wharves, for instance, the crowded state of the floor renders the use of tram lines on the ground almost impossible. In

warehouses, moreover, a large percentage of the floor space must be left unoccupied by merchandise for the purposes of moving about. By the use of such an overhead traveller as here described, much of this can be remedied, the narrow gauge of the tramway rendering it possible to use comparatively sharp curves and so enabling even out of the way corners of the warehouse to be easily reached.

An interesting type of labour-saving apparatus which is now in regular use at some coal mines in Iowa, is the machine for loading coal into box cars, of which an illustration is given on this page. As the coal is dumped from the mine cars, and slides down the chute leading to the railway car, it is deflected in its course by the swinging action of a shovel blade over a curved apron, and deposited right and left into the ends of the car, the distance depending on the speed of the machine, which the operator can regulate at will, thus placing the coal exactly where he wants it. The initial velocity of the coal as it comes down the chute is utilised, requiring slight additional force from the shovel blade to deposit it into the ends of the car, and there is said to be considerably less breakage of friable coal by the use of this machine than when loading by hand is practised in the usual manner, by allowing the coal to fall on a heap in the centre of the car, and then shoveling it into the ends of the car. When the car is loaded to its capacity, the connecting rod from the engines which operate the shovel blade is disengaged, and the slide, or platform, on which the shovel is mounted is withdrawn from the car by a steam piston underneath, requiring the simple throwing of a lever; another car is shoved into place, the steam piston slides the platform back into position and the operation is repeated. The loader is operated by double engines, coupled quartering to the main shaft, and provided with a means of quickly connecting and disconnecting. All the operating levers are within easy reach of the attendant. The capacity of the machine, which has recently been brought out by the Eagle Iron Works, of Des Moines, Ia., is claimed to be limited only by the speed with which the coal can be delivered to it.



A COAL CAR LOADING MACHINE AT THE MINES OF THE W. D. JOHNSON & CO. COAL COMPANY, AT BOONE, IOWA, U. S. A.

A FEW years more and New York City, as enlarged, with its present estimated population of nearly three millions and a half, will produce all its electricity, except that used in small isolated plants, along the river banks. The announcement was definitely made a short time ago that the Metropolitan Street Railway Company of New York ordered from the General Electric Company of the same place five 5000 horse-power street railway generators for its new power-house situated on the East river. These generators are intended to furnish current for all the underground trolley lines now operated by the Metropolitan Company, but as soon as the cable plants which now haul cars on three of the company's lines wear out, they will be replaced by the underground electric system, and eight additional 5000 horse-power generators will be installed in the East river power-house to furnish the current required. This will make this power-house, with its 70,000 H. P., the largest steam plant in the world. Coincident with the announcement of the Metropolitan Company's plans came the news that the Edison Electric Illuminating Company, of New York City, has purchased an acre and a half of ground fronting on the East river, where it proposed to erect the largest electric lighting plant in the United States. Both these companies have followed in the tracks of the City of Brooklyn Street Car Company and the Edison Electric Illuminating Company, of Brooklyn. The street car company just named some years ago erected a model power-house on the Long Island side of the East river, where four direct-connected engines and dynamos of 2000 horse-power output supplied current for the heavy trolley traffic concentrated at the Brooklyn Bridge and the neighbouring ferries. Recently the company ordered two more units of similar capacity, so that there will soon be 12,000 horse-power in six units in this one station. The Edison Company, of Brooklyn, selected an extensive site at Bay Ridge, near the Narrows, which body of water divides New York Harbour into the upper and the lower bay. Here will be erected engines and generators in 2000 H. P. units, with an ultimate output of 12,000 H. P., or more if required.

THE gain in economy by the erection of these large stations along available river banks, instead of away from the water, where most of the electric light and power stations are now situated, will be immense. Land being generally dearer near the centres of cities than at their circumferences, less of it was purchased for these inland stations, as they may be termed, so that, in many cases, economy of space alone dictated the use of non-condensing engines. Then, again, often the water used by the inland stations comes out of the city's supply and has to be paid for at so much per thousand gallons, whereas at tide water the consumption of city water will not only be less, owing to the abundant space for condensing engines, but if a surface condensing plant be adopted, condensing water from the river may be had for the pumping. Much greater than either of these economies, however, is the saving in the cartage of coal and in the disposal of ashes. It costs the Edison Electric Illuminating Company, of New York, 50 cents a ton to haul its coal from the wharf to its present principal station,—a distance of not more than half a mile,—while the same coal is hauled by the railway companies at the rate of half a cent per ton per mile. All this will be changed when the new riverside plants are in operation. The coal will be hauled by rail from the mines to the nearest tide water point, shipped in vessels and brought direct to the wharf at the power-house. It will then be hoisted by electric cranes to bins above the level of the furnaces, whence it will descend by gravity and be fed to the grates by automatic stokers.

THIS plan of placing electric power-houses at tide water and of concentrating several widely scattered small power

plants into one large one is dependent upon improved methods of distributing the electrical current. The method already adopted by the Brooklyn Edison Illuminating Company is likely to be followed without material alteration by the Metropolitan Traction Company and the New York Edison Company. This consists in generating a three-phase alternating current at 6600 volts and in feeding it to the distributing mains without change of voltage. At convenient intervals these mains will supply sub-stations where rotary converters will change the high-tension alternating current into constant current at 500 volts for street railway purposes, and 110 volts for incandescent lighting purposes. The type of generator used for producing such a high voltage has the multipolar field magnets fixed on the revolving shaft, while the armature is attached to the outside ring. In this way the armature requires no collecting rings, and only small rings are required to distribute the energising current to the revolving field magnets. No constant-current commutator could stand such a voltage without a breakdown in the insulation, and it is doubtful if the insulation of even a revolving alternating current armature could withstand such a strain. The economy of transmitting the current is roughly shown by the rule that the loss of voltage on any line increases only inversely as the square of the increase of pressure—that is, for example, if the drop in voltage was 10 per cent. at the end of a line with a dynamo pressure of 3100 volts, it would only be fifteen per cent. with a pressure of 6200 volts.

It has been stated on good authority that a test for stokers, occasionally used in the mercantile marine, consists in having a number of bottomless butter tubs hung shoulder high, ranging the stokers in line before these dummy furnaces, and selecting as the best man the one who shoots a ton of coal through soonest. The whole science and art of stoking, according to this, would seem to lie in the faculty of disposing of the coal rapidly; but this view most engineers probably are scarcely prepared to share without qualification. A man who satisfies the above requirement with flying colours, probably has all the physical requisites for the work that will be expected of him; but what he still needs, if he be new to the business, is actual work at an actual furnace, shoulder to shoulder with an old hand.

The now familiar trolley wheel and its pole in electric railway practice were not always held at their high value of to-day. Mr. William J. Clark, the head of the railway department of the General Electric Company, of New York, in speaking recently, in a reminiscent mood, told of his struggles about ten years ago to sell the patent covering the devices in question. Mr. Clark was then acting as agent for Mr. Van Depoele, the inventor of the underrunning trolley, as it is called. He offered it to one group of American capitalists after another, at an upset price of $100,000, without the slightest success, though he was prepared to dispose outright of the patent for that sum. Finally an offer of $5 for each car fitted with the underrunning trolley was made to him and accepted. Mr. Clark continued that he was happy to say that from this contract he had since paid over to the Van Depoele heirs the sum of $200,000. In his opinion, the three inventions which had brought about the immense development of electric urban and suburban railways were the Sprague patent for motor suspension, the Van Depoele underrunning trolley, and the substitution of carbon for copper brushes on the motor commutator. Mr. Sprague, who installed the first practical trolley line at Richmond, Va., where some of the grades are as steep as 8 per cent., found that with thirty cars in service it cost $9 a day to replace the copper brushes which had vanished into sparks.